

THE PSYCHOLOGICAL REVIEW

MANIFOLD SUB-THEORIES OF "THE TWO FACTORS"¹

BY C. SPEARMAN

PRESENT SITUATION

Few competent judges would dispute that among the most unexpected events in the psychology of the last dozen years has been the sudden spring of 'general intelligence' from an almost universal incredulity to a no less universal investment with the highest importance. In this movement I venture to claim having been among the earliest participants. Already in 1904, I went so far as to put forward an explanatory theory, namely, that of 'Two Factors.'²

The purport of this theory is that the cognitive performances of any person depend upon: (a) a general factor entering more or less into them all; and (b) a specific factor not entering appreciably into any two, so long as these have a certain quite moderate degree of unlikeness to one another.

The proof offered was that, on eliminating from any set of mental tests any that happened to be very obviously like others in the same set, then the intercorrelations may still remain large, but will now admit of being tabulated in a 'hierarchy.' This mode of describing the proof was soon afterwards reduced to the exact mathematical equation:

$$r_{ap}/r_{aq} = r_{bp}/r_{bq}, \quad (\text{A})$$

where *a*, *b*, *p*, and *q* indicate any of the tests and *r* is the

¹ In this paper I owe a double debt to Professor Nunn: firstly, for stimulating me to write; and secondly, for pointing out to me several serious obscurities when I had done so.

² 'General Intelligence,' objectively determined and measured, *Amer. J. Psychol.* 15, 1904.

(product moment) correlation between them.¹ This equation was said, both to hold good of experimental results, and also to prove the said theory. A corollary of the equation is that in any table of correlations as ordinarily set out, every column will have a perfect correlation with every other one. Thus the three criteria, the 'hierarchy,' equation (A), and a perfect intercolumnar correlation all indicate the same theory.

Now, this theory has had a curious fate. It was soon backed up by a seemingly overwhelming mass of evidence.² Above all, even the data expressly brought forward to refute it were without any exception obliged, Balaam-like, to give it their complete support. In particular, a very valuable, but certainly not friendly, investigation of Simpson was shown on more careful reexamination to fulfill the hierarchy just as exactly as all the results obtained before.³ And as for any attempt at disproving this fulfillment by either the data of Simpson or any others that had been adduced, I have laboriously searched the vast literature of mental tests for such in vain. In spite of all this, *mirabile dictu*, hardly any writer (outside of those working in more or less intimate connection with myself) has so far uttered a sign of being convinced!

Of the reasons that might be alleged for this obduracy, some are obviously improbable, such as that so many psychologists should be biased by their preconceived doctrines, or that they would decline to make themselves acquainted with the newer mathematical aids to research.

A more plausible explanation would be some widespread belief that, although the truth of the theory would necessitate the fulfillment of equation (A), yet this fulfillment might not, inversely, necessitate the truth of the theory. But even

¹ This equation was at first expressed in a slightly different form, see *Zeit. f. Psychol.*, 1906, pp. 84-5. Then the form (A) was communicated by the present writer to Mr. Cyril Burt, who employed it in his well-known admirable paper, *Brit. J. Psychol.*, 3, 1909.

² See in particular, 'General Ability, its Existence and Nature,' *Brit. J. Psychol.*, 5, 1912, and 'The Heredity of Abilities,' *The Eugenics Review*, p. 8, 1914.

³ See 'The Theory of Two Factors,' *PSYCHOL. REV.*, 21, 1914.

this suggestion now fails, since a recent luminous paper by Garnett has shown that also this inverse relation holds good.¹ As his demonstration is rather long and difficult (but proportionately instructive), the following very simple one may be of service. It has been used by myself for many years, but never published.

Let r_{xy} denote the correlation between two variable tests, x and y . It can be written as $f(p)$, where p is any one of the elements entering into x and contributing to its correlations, the remaining elements being regarded as parameters. Similarly, r_{xz} may be written as $\phi(q)$, where q is any of the elements entering into and contributing to the correlations of y . But, by equation (A),

$$f(p)/\phi(q) = r_{xy}/r_{xz} = \text{constant.}$$

Hence, p and q cannot possibly be independent of each other; there can be only one independent; and this necessary singleness is at once extensible to the whole set of functions in question.

"A HIERARCHY WITHOUT A GENERAL FACTOR"

Faced, then, on all sides by this elusively silent 'passive resistance' to the theory of Two Factors, it was a great pleasure to myself, anxious to get the matter settled, when at last one (and only one) writer did step into the open field and challenge the above-mentioned evidence on definite grounds. This was G. H. Thomson, the tenor of whose argument was to admit that the theory is proved whenever equation (A) is satisfied *exactly*, but to deny that it even approaches being proved whenever (A) is only satisfied with close approximation.²

Very possibly, indeed, it is just this paper which has been in large measure responsible for the said 'passive resistance.' This would appear to be indicated by such statements as the following:

"Thomson has shown in a recent paper that Spearman's

¹ 'On Certain Independent Factors in Mental Measurements,' *Proc. Roy. Soc., A*, **96**, 1919.

² 'A Hierarchy without a General Factor,' *Brit. J. Psychol.*, **8**, 1916.

method of calculation of data which led to his conclusion of the existence of a general intellective factor—a ‘general ability’ as against special abilities—is open to the gravest criticism. Thomson attacks the concept on purely mathematical grounds, but his reasoning would appear to be unquestionably accurate.”¹

As to whether this final comment can be accepted without reservation we shall see shortly. But in any case Thomson’s method of proof is a notable contribution to the subject and will serve, I believe, to clear up much obscurity and misunderstanding.

He constructed tables of correlations artificially, by an extension of the method of Weldon.² Each function—here representing the marks obtained in a single test by a single individual—consisted in the total throw of a set of dice. Of course, there was a separate throw made for each individual. But there was not a completely separate throw for each test; instead, some of the dice were marked beforehand and their resulting points were counted for two or more tests in common. The result is a correlation amounting, as Weldon showed, to the proportion of dice used in common; thus, if 4 dice were counted to two tests in common, whilst 6 other dice were thrown for each test separately, then the correlation between the two would on a large number of throws tend towards $4/10 = .4$. Moreover, instead of going through the tedious operation of making the throws actually, the result of an infinite number of them can easily be obtained theoretically; it is given by

$$r = 1/\sqrt{(c+m)(c+n)}$$

where c is the number of dice used in common, while m and n are those used each for one only of the two functions.³

Proceeding in this manner, Thomson constructed the fol-

¹ Fernberger, *J. of Appl. Psychol.*, 1, p. 197, 1917.

² Cited by Edgeworth, *Encycl. Brit.*, 10th ed., XXVIII., p. 282.

³ The equation at once got from the ‘Correlations of Sums or Differences,’ *Brit. J. Psychol.*, 5, p. 419, equation (2). The term on the right hand becomes:

$$\frac{c(r=1) + S(r=0)}{\sqrt{c+m+2S(r=0)} \sqrt{c+n+2S(r=0)}}$$

lowing arrangement, in which 36 of the elements (dice) 'run through more than one test each, but never through all.'

TABLE I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
a.....	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x			
b.....	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
c.....	x	x	x		x	x			x	x			x						
d.....	x		x	x		x		x		x		x		x	x				
e.....		x						x		x		x					x	x	
f.....		x					x	x		x							x	x	
g.....			x			x						x							
h.....				x							x					x			
k.....					x						x			x			x	x	
l.....						x					x				x			x	
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	S
a.....				x			x		x	x	x		x	x	x	x	x	0	
b.....						x	x	x	x	x	x	x	x	x	x	x	x	0	
c.....					x	x	x	x	x	x	x	x	x	x	x	x	x	1	
d.....					x	x	x	x	x	x	x	x	x	x	x	x	x	3	
e.....					x					x	x	x	x	x	x	x	x	9	
f.....	x	x		x	x			x		x	x		x	x	x	x		14	
g.....	x		x	x	x			x		x		x						16	
h.....		x	x	x	x				x		x							20	
k.....	x	x	x	x						x								22	
l.....	x	x	x	x														24	

In this table, the heading numbers denote the dice thrown, while the letters are the tests to which they were counted. Under the heading S, are given the number of throws counted only to a single test, namely that indicated by the letter in the same row.

Now, from this arrangement of the dice there resulted the following set of intercorrelations of the tests [Table II.]

In this Table, he says, the columns correlate with one

TABLE II

	a	b	c	d	e	f	g	h	i	j
a.....		867	730	593	356	174	167	120	116	112
b.....	867		650	550	341	143	137	088	084	082
c.....	730	650		500	292	143	091	088	084	041
d.....	593	550	500		244	095	091	088	042	041
e.....	356	341	292	244		093	089	043	041	040
f.....	174	143	143	095	093		044	042	040	039
g.....	167	137	091	091	089	044		040	039	037
h.....	120	088	088	088	043	042	040		037	036
k.....	116	084	084	042	041	040	039	037		034
l.....	112	082	041	041	040	039	037	036	035	

another, not indeed exactly, but quite as well as in the cases adduced by me on behalf of the theory of a general factor, and yet in his arrangement given above there is 'nothing approaching a general factor.' From this he concludes that the question as to whether mental tests really do demonstrate the existence of a general factor will require 'a very much more extensive set of experiments than has yet been attempted.' And as he remarks that even a thousand cases would be insufficient, the outlook for further research would appear to be arduous.

This demonstration, unfortunately, was brought forward at a time which to me appeared inopportune for scientific controversies. Hence, my reply consisted—unpardonably, save for the extraordinary circumstances—in a brief note, not so much giving my arguments, as indicating what general lines they would in due course follow.¹

For one thing, it was indicated that this new view could be shown not to rest upon a solid foundation by the fact of its proposing to settle the point through more extensive experiments; my note suggested, on the contrary, that not even a million cases could possibly produce a hierarchy distinguishable from such as could be constructed by the new method. This suggestion I will now endeavor to justify, showing that by such a method even the most perfect hierarchy can be constructed. Suppose, for instance, that we wanted to get the following tables of correlations between the tests (or other functions) *a*, *b*, *c*, *d*, and *e*, where the columns intercorrelate quite perfectly and equation (**A**) is satisfied exactly.

TABLE III

	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>
<i>a</i>		40	30	20	10
<i>b</i>	40		24	16	08
<i>c</i>	30	24		12	06
<i>d</i>	20	16	12		04
<i>e</i>	10	08	06	04	

Following the new method precisely, we can at once get this Table III. if we put together our dice or other elements in the following manner [Table IV]:

¹ *Brit. J. Psychol.*, 8, 1916, p. 284.

TABLE IV

Tests	Dice													
	1 to 20	21 to 35	36 to 47	48 to 57	58 to 65	66 to 71	72 to 76	77 to 80	81 to 83	84 to 85	86 to 91	92 to 105	106 to 129	130 to 165
a....	x	x		x			x				x			
b....	x		x		x		x				x			
c....		x	x		x			x			x			
d....			x	x	x			x		x		x		
e....						x	x	x	x			x		x

The above table means that, for instance, the first 20 dice have entered into tests *a* and *b* only; the next 15 dice into *a* and *c* only; similarly, the others. Obviously enough, purely specific dice may be added to any extent and in any manner, without disturbing the hierarchy at all.

Thus, the new argument against the theory of Two Factors proves *too much*. By its results—since the theory is admittedly true when (**A**) is satisfied exactly—it comes to suicide.

THE DICE HIERARCHIES FURNISH NO EVIDENCE

But the preceding conclusion leaves us with a paradox. How are we going to explain the seeming fact that the arrangement given in Table IV. does *not* assign any of the dice to all the tests, or indeed to more than two? My original note asserted that Thomson had, after all, let in a general factor by a ‘back door.’ Where is there any such thing? And of what nature is the general factor really? And of what nature is it?

Moreover, some justification is needed for the charge in my note against the dice arrangements as being “arbitrary.” We will take this last point first. Let M_{ax} and M_{px} denote the total marks obtained by the individual x in the tests *a* and *p* respectively, so that

$$M_{ax} = A_1\alpha_{1x} + A_2\alpha_{2x} + \cdots + A_m\alpha_{mx} + R_{ax},$$

and

$$M_{px} = P_1\alpha_{1x} + P_2\alpha_{2x} + \cdots + P_m\alpha_{mx} + R_{px},$$

where the α 's denote the elements (dice) common to any two or more of *all* the tests belonging to the domain in question, any of the A 's or P 's may be either + 1 or 0, and the R 's

denote the sums of the elements specific to the two tests respectively.

Let each M and also each α be measured from its arithmetical mean for all individuals as origin; and let the units of measurement be such that the sum of the squares of M for all individuals is in each test = 1. Then, $A_h \cdot P_k \cdot \Sigma_x(\alpha_{hx} \cdot \alpha_{kx})/n = 0$, if the elements h and k are different; but if they are the same, it may be written as $A_h' \cdot P_k' \cdot \Sigma(\alpha^2)/n$, where $\Sigma(\alpha^2)$ is constant for all elements. Hence, we get for the correlational coefficient between a and p :

$$\begin{aligned} r_{ap} &= \Sigma_x(M_{ax} \cdot M_{px}) \\ &= A_1' \cdot P_1' \cdot \Sigma_x(\alpha_{1x}^2) + \cdots + A_{m'}' \cdot P_{m'}' \cdot \Sigma_x(\alpha_{mx}^2) \\ &= \Sigma(\alpha^2)(A_1' \cdot P_1' + \cdots + A_{m'}' \cdot P_{m'}'), \end{aligned} \quad (\mathbf{B})$$

Using analogous symbols for another test q , and assuming the validity of equation (A), there results immediately:

$$A_1' \cdot P_1' + \cdots + A_{m'}' \cdot P_{m'}' = \lambda(A_1' \cdot Q_1' + \cdots + A_{m'}' \cdot Q_{m'}'), \quad (\mathbf{C})$$

or

$$A_1'(P_1' - \lambda Q_1') + \cdots + A_{m'}'(P_{m'}' - \lambda Q_{m'}') = 0. \quad (\mathbf{D})$$

Let us now, keeping the tests p and q constant, allow a to change its constitution. For every variation of it we get, if (A) holds good, another equation of the same form as (D). But there cannot simultaneously subsist a greater number of independent equations having that form than $m_b' - 1$, where m_b' is the number of A 's having any of their coefficients in these equations not zero. Hence, the variation of a satisfying (A) are confined to $m' - 1$ points, and therefore cannot possibly cover any continuous (or even 'dense') region at all, however minute; for any such has an infinity of points. We cannot even take m' to be very large, for then the luck of the throwing would be equalized for the different individuals, giving them all equal average marks, so that no correlation would be determinate at all. This proves that, whatever import the dice hierarchies may possess, at any rate they do not touch the evidence arrayed on behalf of the Theory of Two Factors, for there the test a was by no means confined to a set of selected points, but, in general, varied at random. The objection against arguing from values selected arbitrarily appears, then, to be substantiated.

WHERE THE GENERAL FACTOR LIES

But although the dice hierarchies are thus once more put out of court as regards the controversial employment attempted, nevertheless their intrinsic interest may well claim for them some further examination. In particular, we have not yet found out what actually constitutes the general factor in tables such as II. and III.

Now, for M_{ax} really to consist of a latent general factor together with a specific factor (as maintained by the theory in question) it is *necessary* if these factors are additive, and it is *sufficient* in any case, that we should be able to re-write

$$M_{ax} \text{ as } w_a \cdot g_x + s_{ax} \equiv w_a \cdot h_x \cdot g + s_{ax}, \quad (E)$$

where g_x is some function of the α 's, g is its mean value and thus constant throughout, h_x is constant for the individual x with all tests, w_a is constant for the test a with all individuals, whilst s_{ax} varies from individual to individual independently of both g_x and s_{bx} (b indicating any further test).

Let us see, then, whether and how the above conditions for g_x , s_{ax} and w_a are fulfilled by equation (A).

We require, first, $r_{(g_x)(s_{ax})} = 0$.

But this coefficient $= r_{(g_x)(M_{ax}-g_x)} = \sigma_g \cdot r_{ag} - w_a \cdot \sigma_g^2$, expanding by known formula¹ and remembering that

$$\sigma_{M_{ax}}^2 = w_a^2 \cdot \sigma_g^2 + \sigma_{sa}^2 = 1.$$

Hence, our condition will be fulfilled by $r_{ag} = w_a \cdot \sigma_g$, which we may write as w_a' .

We also want $r_{(s_a)(s_b)} = 0$. But this equality, as we see by similarly expanding r_{ab} into $w_a \cdot w_b \cdot \sigma_g^2 + \sigma_{sa} \cdot \sigma_{sb} \cdot r_{(s_a)(s_b)}$, will hold good when

$$r_{ab} = w_a \cdot w_b \cdot \sigma_g^2 = w_a' \cdot w_b' \quad (F)$$

Actually by equation (A), on the other hand,

$$\begin{aligned} r_{ab} &= r_{ap} \cdot r_{bq} / r_{pq} = r_{bp} \cdot r_{aq} / r_{pq} \\ &= [(r_{ap} \cdot r_{aq})^{1/2} \cdot r_{pq}^{-1/2}] [(r_{bp} \cdot r_{bq})^{1/2} \cdot r_{pq}^{-1/2}] \end{aligned} \quad (G)$$

for all combinations of p and q ; it therefore may be written as $v_a \cdot v_b$ and thus has precisely the form required by (F).

¹ 'Correlation of Sums or Differences,' *Brit. J. Psych.*, V., 1913, p. 419.

There only remains, then, to so determine the function g_x that w_a' or $r_{ag} = v_a$. This done, w_a can at once be taken as v_a/σ_g .

Such a determination is readily supplied by the sum of the scores of the individual x in all the tests. For then, expanding as before,

$$\begin{aligned} r_{ag}^2 &\equiv r_{(a)(a+b+\dots+z)}^2 \\ &= [1 + r_{ab} + \dots + r_{az}]^2/[z + 2S_p(r_{ap}) + 2S_{pq}(r_{pq})], \\ &\text{where } p \text{ and } q \text{ take all values different from each other and from } a, \text{ whilst } z \text{ is the number of tests,} \\ &= [(z - 1)(z - 2)\overline{r_{ap} \cdot r_{aq}} + 2(z - 1)\overline{r_{ap}} + (z - 1)\overline{r_{ap}^2} + 1] \\ &\quad \div [(z - 1)(z - 2)\overline{r_{pq}} + 2(z - 1)\overline{r_{ap}} - 1] \\ &= \overline{r_{ap} \cdot r_{aq}/r_{pq}} = v_a^2, \text{ again just as required,} \quad (H) \\ &\text{where the scorings indicate means for all combinations of } p \\ &\text{and } q, \text{ in the case of the equation (A) holding good for any} \\ &\text{finite domain (as it actually does, according to the empirical} \\ &\text{evidence), so that } z \text{ becomes infinitely large and its lower} \\ &\text{powers vanish in comparison with the squares.} \end{aligned}$$

Even in the case of equation (A) applying only to some isolated points, our expression for g_x remains an approximation, and can easily be made exact by appropriately changing the relative weights of the α 's entering into it.

On the whole, then, g may be regarded as the unit of "General Intelligence," h_x indicating how much of it is possessed by the individual x , whilst w_a shows what relative scope for its influence is afforded by the test α .

This analysis of the general factor and its properties derives no little interest from the fact that our whole argument, although based on the dice correlations, is at once capable of generalization to all product-moment correlations whatever, merely by removing the restriction of the A 's, B 's, etc., to the values of +1 and 0. This follows readily if we (with Bravais himself) assume that any of the functions concerned can be represented with sufficient approximation by Taylor's expansion to the first differentials. For then we get, using f as the symbol of function:

$$f(\alpha_1, \alpha_2, \dots, \alpha_z) = A_1 \cdot \alpha_1 + A^2 \cdot \alpha_z^2 + \dots + A_z \cdot \alpha_z,$$

where the A 's are now the first differential coefficients and may have any values.

FORM OF EXPRESSION

There was yet a fourth pledge in my original note, namely to show that the dice hierarchies, besides re-introducing the general factor unnoticed, did so in a *form* that was psychologically altogether untenable.¹ This pledge also, I will now try to redeem, but with the qualification that such psychological untenability must not be taken to imply psychological lack of importance and interest.

If we consider generally the form and the fact of dependence, the difference between them appears to be profound. As regards the fact, a function contains, in general, a determinate number of totally independent variable elements; this number measures its grade of freedom, its dimensionality. But the function's form of expression, on the contrary, can introduce any number desired of what may be called partially independent variables. For example, x can always be transformed into $a_1x_1 + a_2x_2 + \dots + a_nx_n$, where x_1, x_2, x_{n-1} as also $a_1, a_2 \dots a_n$, may have any values whatever, so long as the power is retained of connecting them together again by means of the still remaining x_n . The latter need only be made $= (x - a_1x_1 - \dots - a_{n-1}x_{n-1})/a$. Or, instead of introducing x_n among the variables, some condition imposed on them (as done by equation A) can have just the same effect. Again, any function of any two variables, x and y , can equally well be expressed as functions of two fresh variables, for instance, of r and θ where $r^2 = x^2 + y^2$ and $\tan \theta = y/x$; r and θ are just as independent of each other as were x and y .

In many cases, the choice of form between the infinitely numerous possible alternatives is dictated merely by convenience or lucidity. But in other cases, the form, even if it does not positively state, at any rate strongly suggests, some facts. In physics, for instance, all the units employed are mathematically reducible to those of mass, length, and time.

¹ *Brit. J. Psychol.*, 1916, 8, p. 284.

Yet in practice, such highly significant units are usually employed as 'force' ($= MLT^{-2}$), or of 'work' ($= ML^2T^{-2}$), or even of 'power' ($= ML^2T^{-3}$). Here, whilst the number of totally independent elements constitute the fundamental theory, the form of expression implies a *sub theory*.

If, now, we look at the properties of our general factor shown to be latent in the dice hierarchies, we see from (*D*) that they happen to be of the class that do imply facts. For they are such that any of the α 's entering into any test indicated by a can disappear when the a passes to b indicating another test, but then some other α is obliged to arise in its place in order to keep the correlation with any further test b still in accordance with equation (*D*).

Does not this imply that, the more the test b resembles the first test indicated by a , the more it must resemble the second test so indicated however unlike the first one?

And is not this result absurd? The answer to both questions, I think, must be in the affirmative, so long as the α 's denote any *phenomenological* characters whatever. And by 'common elements' psychologists do, as a matter of fact, habitually mean something phenomenological. But suppose that, instead, we transcend the universe of phenomena and take the α 's to denote portions of some hypothetical underlying 'force' which is equally effective for varied phenomena. Upon this basis, there is no longer any absurdity, but a necessity, that for any lost α , there should always become available another one. With such interchangeable force, however, we have arrived at neither more nor less than the hypothesis of a common fund of energy (and incidentally, we have in large measure transferred the burden of further proof from psychology to physiology).

It may be observed that essentially the same position reoccurs in the recently published view of Otis, according to which each test has its own particular degree of 'spread' of elements.¹ For on this view, the fact of test p 'spreading' so as to contain many common elements with test a_1 involves its also 'spreading' so as to contain many common elements with any other test a_2 .

¹ *J. Educ. Psychol.*, 1918, 9, p. 345.

Another form of expression may perhaps be derived from the very interesting work of McCall.¹ He finds that in several cases the intercolumnar correlations, far from approaching to + 1.00, come very nearly to the exact opposite, - 1.00. This, he urges is in polar contradiction to the Theory of Two Factors. But such an argument rests upon a mere misapprehension (quite possibly due to unprecise wording on my part); for it has long been noticed by Webb² that equation (*A*) is just as well satisfied by negative as by positive intercolumnar correlations, so long as they approach unity. Moreover, it is even perfectly true to say that the intercolumnar correlation is always + 1.00, so long as the reservation is made that the units of measurements should be chosen suitably. By this reservation, the positive sign can at once be restored throughout the intercolumnar correlations of both Webb and McCall. But even then, there may be indications of a new and important sub theory.

Yet another instance of a sub theory is in the course of being elaborated by the investigator already quoted, Thomson; this is that of a hierarchy arising from "Two Levels" of mental process.³ At present, his only published evidence is 'an arrangement actually arrived at in a trial': and the value of such a single arbitrarily selected case in a statistical investigation seems to me, I must admit, open to gravest question. But when he has supplemented this by a determination of the amount of intercolumnar correlation produced by his conditions *on an average*, and has found that this average approaches to unity—thereby showing that the general factor has come in once more—then his view may lead to very interesting developments.

To close, a word may be allowed as regards my own attitude towards all these sub theories. For a long time, I have suggested their possible diversity. And—although my present preference may have made itself manifest—I

¹ Teachers College, Columbia University Contributions to Education, No. 79, 1916. The very newness of his results as compared with those obtained by other researches, however, must make us demand a proportionately ample corroboration.

² 'Character and Intelligence,' *Mon. Suppl., Brit. J. Psychol.*, 1915, p. 56.

³ *Brit. J. Psychol.*, 9, 1919, p. 337 ff.

certainly never have claimed that any considerable evidence has been produced *as yet* (either by myself or by any one else) for or against any one of them. Nor, I am inclined to think, will they ever admit of absolutely decisive evidence, since they appear to involve hypotheses incapable of more than relative probability; these hypotheses, like those involved in the theory of light, or of electricity, may always—even after a long reign of acceptance and usefulness—be suddenly upset again.

But as regards the fundamental theory, I venture to maintain that this has now been demonstrated with finality. It involves no hypothesis whatever, but is a direct mathematical deduction from equation (A). Nothing I can conceive will shake it, unless it be detecting some flaw in the mathematical logic, or convicting all those investigators whose work supports (A) of a vast conspiracy. So it would seem as if psychologists have now got definitely to accept this Theory of Two Factors; it becomes a Bed of Procrustes, into which all our doctrines must somehow or other be made to fit, even though the so doing may at times involve a not unpainful surgical operation upon them.

GENERAL VERSUS GROUP FACTORS IN MENTAL ACTIVITIES

BY GODFREY H. THOMSON

Armstrong College, University of Durham

I. OBJECTS OF THE PAPER

The objects of this paper are to give a general summary, in non-mathematical language, of various scattered papers which in the writer's opinion prove the invalidity of the reasoning upon which Professor Spearman has based his Theory of General Ability, or Theory of Two Factors: to submit an alternative theory, which may be called the Sampling Theory of Ability, explaining the known facts of mental correlation at least equally as well as does Professor Spearman's theory: and, while admitting that the existence of general ability is still possible, though unproven, to give reasons in support of the greater probability of the Sampling Theory. The two theories are not necessarily exclusive of one another.

II. HISTORICAL

The controversy as to whether ability in any individual is general, or specific, or in groups or 'faculties' is a very old one, but for the purposes of the present article it is not necessary to go back prior to the above mentioned paper,¹ the first of a series in which Professor Spearman has developed his Theory of General Ability, or Theory of Two Factors, as it is alternatively named.

Professor Spearman's method in that paper was to measure a number of mental abilities, some of them school subjects, others artificial tests, in a number of persons, and calculate the correlation coefficients of each of these activities with each of the others. These correlation coefficients, he then noticed, had a certain relationship among themselves, a rela-

¹ 'General Intelligence objectively determined and measured,' C. Spearman, *Amer. J. Psychol.*, 1904, 15, pp. 201-293.

tionship which may be called hierarchical order, and is explained in detail in the technical papers on the subject. He saw, quite rightly, that the presence of a general factor would produce this hierarchical order among the coefficients and, reversing this argument, he concluded that the presence of hierarchical order proved the existence of a general factor

A number of experimental researches on these lines, in some of which Professor Spearman himself took part, followed during the next eight years, but with very conflicting results, some experimenters finding the hierarchical order among the coefficients, others finding no such order. Two of the best articles of this period are those of Mr. Cyril Burt,¹ who found practically perfect hierarchical order, and Dr. William Brown,² who found no trace of such order. The experimental work in each case was psychologically of a high degree of excellence.

Things were in this very unsatisfactory state when an important article by Professor Spearman, in coöperation with Dr. Bernard Hart, appeared in 1912.³ In this article the difficulty of making an unbiased judgment as to the presence or absence of hierarchical order was recognized, and a form of calculation was given for obtaining a numerical criterion of the degree of perfection of hierarchical order, which criterion would be independent of any bias on the part of the calculator. This criterion ranges theoretically from zero, for absence of hierarchical order, to unity, for perfection of hierarchical order. But their formula can, arithmetically, exceed unity.

The authors applied their criterion to all the experimental work available, work dating from various periods, and representing the researches of 14 experimenters on 1,463 men, women, boys and girls. From beginning to end the values of the criterion were positive and very high. The mean was

¹ Cyril Burt, 'Experimental Tests of General Intelligence,' *Brit. J. Psychol.*, 1909, 3, pp. 94-177.

² William Brown, 'Some Experimental Results in the Correlation of Mental Abilities,' *Brit. J. Psychol.*, 1910, 3, pp. 296-322.

³ 'General Ability, its Existence and Nature,' by B. Hart and C. Spearman, *Brit. J. Psychol.*, 1912, 5, pp. 51-84.

almost complete unity. That is to say, Dr. Hart and Professor Spearman claimed that all the data then available showed perfect hierarchical order among the correlation coefficients, even the data of workers like Dr. Brown and Professor Thorndike, who had been unable to detect any such order.

The reasons why the hierarchical order among the correlation coefficients was not obvious at a glance were, according to these authors, two. In the first place, their theory did not entirely deny the presence of group factors of narrow range, and tests which were too similar were, according to them, to be pooled, before the hierarchical order would become apparent. Only in very few cases, however, did they find it necessary to pool tests in the data used. In the second place, the obscuring of the perfect hierarchical order was, according to them, due to the fact that only a small sample of subjects is examined. For this error allowance is made in the formula for calculating their criterion.

Dr. Hart and Professor Spearman therefore considered their 'Theory of Two Factors' proved. This theory considers ability in any activity to be due to two factors. One of these is a general factor, common to all performances. The other is a specific factor, unique to that particular performance, or at any rate extending only over a very narrow range including only other very similar performances. "It is not asserted," they say, "that the general factor prevails exclusively in the case of performances too alike, but only that when this likeness is diminished, or when the resembling performances are pooled together, a point is soon reached where the correlations are still of considerable magnitude, but now indicate no common factor except the general one."

In the same paper Dr. Hart and Professor Spearman consider, and in their opinion confute, two other theories, (a) the older view of Professor Thorndike, viz., a general independence of all correlations, and (b) Professor Thorndike's newer view of 'levels,' or the almost universal belief in 'types.' If the former were true, their criterion would, they consider, show an average value of about zero: if the latter, a low minus value.

Many experimental researches were inspired by this paper of Dr. Hart and Professor Spearman, of which, as a good example, may be cited one in 1913 by Mr. Stanley Wyatt.¹ It is I think not too much to say that in practically all of these the application of the Hart and Spearman criterion gave values closely approximating to unity and therefore supporting the Theory of General Ability. But complications began to arise, of which the first of importance will be found in Dr. Edward Webb's monograph on 'Character and Intelligence,' in 1915.² Dr. Webb considered that he had found (in addition to Professor Spearman's General Ability), a second general factor, which he calls 'persistence of motives.' Other writers began to find that their data required for their explanation large group factors, of wider range than those contemplated in the original form of Professor Spearman's theory.³ Quite recently Mr. J. C. Maxwell Garnett, discussing the data of a number of workers with the aid of mathematical devices which he has introduced for the purpose, concludes that in addition to the single general factor of Professor Spearman, there are two large group factors which are practically general⁴ (one of them being indeed almost identical with Dr. Webb's second general factor), which he calls respectively 'cleverness' and 'purpose,' both distinct from general ability.

It is clear therefore that in any case the simple original form of Professor Spearman's theory is becoming complicated by additions which tend to modify it very considerably. Meanwhile, however, the present writer had come to the conclusion that the mathematical foundations upon which it was based were in fact incorrect. Before developing the line of argument which led to this, it will be well to re-state Professor Spearman's case in its simplest terms in a few words.

¹ Stanley Wyatt, 'The Quantitative Investigation of Higher Mental Processes,' *Brit. J. Psychol.*, 1913, 6, pp. 109-133.

² E. Webb, 'Character and Intelligence,' *Brit. J. Psychol., Monog. Suppl.*, 1915, 3, pp. ix and 99.

³ See especially E. Carey, 'Factors in the Mental Processes of School Children,' *Brit. J. Psychol.*, 1916, 8, pp. 170-182.

⁴ J. C. Maxwell Garnett, 'General Ability, Cleverness, and Purpose,' *Brit. J. Psychol.*, 1919, 9, pp. 345-366.

It is entirely based upon the observation and measurement of hierarchical order among correlation coefficients. It states that after allowance has been made for sampling errors this hierarchical order is found practically in perfection. And it finally states that such a high degree of perfection can only be produced by a general factor, and the absence of group factors, which would mar the perfection.

III. THE CASE AGAINST THE VALIDITY OF PROFESSOR SPEARMAN'S ARGUMENT

It is possible, by means of dice throws or in other ways, to make artificial experiments on correlation, with the immense advantage that the machinery producing the correlation is known, and that therefore conclusions based upon the correlation coefficients can be confronted with the facts. Working on these lines, the present writer made, in 1914, a set of imitation 'mental tests' (really dice throws of a complicated kind) which were known to contain no general factor. The correlations were produced by a number of group factors which were of wide range, and, unlike Professor Spearman's specific or narrow group factors, they were not mutually exclusive.

These imitation mental tests, containing no general factor, gave however a set of correlation coefficients in excellent hierarchical order, and the criterion was when calculated found to be unity, so that had these correlation coefficients been published as the result of experimental work, they would have been claimed by Professor Spearman as proving the presence of a general factor.¹

In a short reply Professor Spearman laid stress on the fact that this arrangement of group factors which thus produced practically perfect hierarchical order was not a random arrangement, and that it was exceedingly improbable that this one special arrangement should have occurred in each of the psychological researches of many experimenters, so improbable indeed as to be ruled entirely out of court.²

¹ Godfrey H. Thomson, 'A Hierarchy without a General Factor,' *Brit. J. Psychol.*, 1916, 8, pp. 271-281.

² C. Spearman, 'Some Comments on Mr. Thomson's Paper,' *Brit. J. Psychol.*, 1916, 8, p. 282.

It is clear that Professor Spearman did therefore definitely admit that at any rate one arrangement of group factors existed which would give hierarchical order of sufficient perfection to satisfy completely his criterion. He did more than this, however, for he claimed already to have published, without proof, in an earlier paper, what the effect of a really random overlapping of all the factors in his opinion is, namely that in this case his criterion will be of the same value as the average correlation between the tests.¹ Now the average correlation between the tests employed in the psychological researches under consideration is not as a rule low. Indeed in those tests which really play an important part in the calculation of the criterion it is usually very high. So that this criterion would, if Professor Spearman's admission be correct, apparently be high on the random overlap theory; that is to say sheer chance would produce considerable though not perfect hierarchical order. This already puts the proof of the Theory of General Ability into a very different position from that which it appeared to occupy immediately after the publication of the paper of Dr. Hart and Professor Spearman in 1912. For in that paper the alternative theories gave values of the criterion which were either zero or negative, and the fact that it actually came out to be almost unity seemed conclusive. But now the comparison is much less definite, for here is a theory which may give high positive values. The criterion must not merely be high and positive to prove the Theory of Two Factors, it must be absolutely unity. True, in Professor Spearman's calculations it does come to unity with most remarkable regularity. But if it can be shown that these calculations are in any way erroneous, then the fact that the comparison is with a theory which can give a high criterion, and not merely with theories which give zero or less, is of great importance.

One reply which Professor Spearman might make to this step of the argument is contained by implication in the footnote on page 109 of the already quoted 1914 article in the

¹ C. Spearman, 'The Theory of Two Factors,' PSYCHOL. REV., 1914, 21, p. 109. See also E. Webb, 'Character and Intelligence,' *Brit. J. Psychol. Monog. Suppl.*, 1915, No. 3, on page 57 and Appendix, page 82.

PSYCHOLOGICAL REVIEW. He appears to think that on the random overlap theory the criterion and the average correlation, though equal, will both be zero or very small on the average. In other words, on this view random overlap will produce hierarchical order if it produces correlation at all, but usually both will be zero. To return to the reply of Professor Spearman to the 'Hierarchy without a General Factor,' the reply namely that this special arrangement would doubtless give such order, but was too improbable to be seriously considered, and that a random arrangement of Group Factors, though it might give some hierarchical order, would not give it in the perfection actually found: the obvious way to find out if this is so or not is to try it, with artificial 'mental tests' formed of dice throws. This the present writer did in November and December of 1918, after an unavoidable delay of some years. Sets of artificial variables (analogous to the scores in mental tests) were made, in each of which the arrangement of group factors was decided by the chance draws of cards from a pack.¹ It was found that in every case a very considerable degree of perfection of hierarchical order was produced, quite as high as that found in the correlation data of experimental psychology. A further test was made on that set of data, from among these artificial experiments, which appeared to yield the least perfect hierarchical order. The true values of the correlation coefficients being known, the true degree of perfection of hierarchical order could be correctly calculated, and was 0.59 (perfection being represented by unity). Dice throws were now made to obtain experimental values of the same correlations, and Professor Spearman's criterion applied. As it has done in the case of so many experimental researches in psychology, *it gave the value unity.*² This set of correlation coefficients, therefore, if it had been published as the result of experiments on mental

¹ Godfrey H. Thomson, 'On the Cause of Hierarchical Order among the Correlation Coefficients of a Number of Varieties taken in Pairs,' *Proceedings of the Royal Society of London*, 1919, A, 95, pp. 400-408. See also, by the same author, 'The Hierarchy of Abilities,' and 'The Proof or Disproof of the Existence of General Ability,' in *Brit. J. Psychol.*, 1919, 9, pp. 321-344.

² Godfrey H. Thomson, 'On the Degree of Perfection of Hierarchical Order among Correlation Coefficients,' *Biometrika*, 1919, Vol. 12, pp. 355-366.

tests, would have been claimed by Professor Spearman as additional proof of the existence of a general factor, although in fact there was no such general factor present, and the correlations were due to *randomly* selected group factors.

The conclusions which appear reasonable from this are (a) that hierarchical order, unless perhaps when it is absolutely perfect, is no proof of the existence of a general factor, and (b) that the Hart and Spearman criterion for hierarchical order is somehow incorrect, and exaggerates the degree of hierarchical order present.

The errors which cause this exaggeration are pointed out in the last cited article in *Biometrika*, and are mainly two. In the first place, Dr. Hart and Professor Spearman assumed certain quantities to be uncorrelated when they are really strongly correlated, though in a peculiar manner. This error causes the possible values of the criterion to be distributed, not from zero to unity, but from zero to infinity. In the second place, they employ a 'correctional standard' which rejects all the values greater than about $1\frac{1}{2}$. The possible range for the accepted values is in practice from about $\frac{1}{2}$ to $1\frac{1}{2}$, and their average is naturally about unity. In other words, the remarkable regularity with which this criterion gives the value unity is not a property of the investigated correlation coefficients at all, but is a property possessed by the criterion itself, due to errors and the action of the 'correctional standard.'

In the writer's opinion the work outlined in this section of the present paper finally proves the invalidity of Professor Spearman's mathematical argument in favor of the Theory of Two Factors. If this be so that theory returns to the status of a possible, but unproven, theory.

IV. HIERARCHICAL ORDER THE NATURAL ORDER AMONG CORRELATION COEFFICIENTS

The fact is that hierarchical order, which Professor Spearman was the first to notice among correlation coefficients, is the natural relationship among these coefficients, on any theory whatever of the cause of the correlations, excepting

only theories specially designed to prevent its occurrence. It is the *absence* of hierarchical order which would be a remarkable phenomenon requiring special explanation; its presence requires none beyond what is termed chance.

An analogy from the simple repeated measurements of a linear magnitude may help to illustrate this. Indeed it is rather more than an analogy, being in fact the same phenomenon in its simplest terms and dimensions. It is well known that many measurements of the same quantity, made with all scientific precautions, under apparently the same conditions, and with an avoidance of all known sources of error, nevertheless do not give a number of identical values. The values are all different, but are not without law and order in their arrangement. They are grouped about a center from which the density decreases in both directions, and it is found that this grouping is for most practical purposes closely represented by the Normal or Gaussian Curve of Error. Experimenters are not surprised to find their data obeying the Normal Law, nor do they require a special theory to explain it. On the contrary, it is the departures from the Normal Law which if wide would cause alarm and require special investigation, and if confirmed would require a special theory. In the same way hierarchical order among correlation coefficients should not cause surprise, though any marked variation from this order would demand investigation.

Correlation coefficients are themselves correlated, and n correlation coefficients form an n -fold or n -dimensional correlation-surface. The particular and convenient form of tabulation of correlation coefficients adopted by Professor Spearman and followed by most other psychological workers brings to light, in the form of "hierarchical order," one of the properties of this correlation-surface of the correlations.

It is true that in the ordinary form of the theory of correlation of correlations,¹ the variations in the correlation coefficients to which the correlation of these coefficients refers, are variations due to sampling the population; *i.e.*, to taking

¹ K. Pearson and L. N. G. Filon, 'On the Probable Errors of Frequency Constants and on the Influence of Random Selection on Variation and Correlation,' *Phil. Trans. of the Roy. Soc. London*, 1898, 191 A, pp. 299-311.

in our case a class of only perhaps 50 English grammar school boys of age 12, instead of all such boys: whereas the hierarchical order we desire to explain is already found in the true 'theoretical' correlation coefficients. This difference is however one of point of view only. It was left partially unexplained in the above cited article¹ although it was referred to. Further consideration leads to the following resolution of the difficulty.

Suppose that n variates (in our work the scores in mental tests) are so connected by factors that the correlations are all equal and positive. Then let a small sample of the population be taken. The *observed* correlations will show departures from equality, and will be found to be in hierarchical order. This hierarchical order is due to sampling the population.

Now consider why the correlations do not come out at their true values. They give of course the true values *for the sample*. The reason of their departing from the true values of the whole population is that (a) some of the factors which really are links between the variates (the mental activities) happen to have remained steadier than usual during the sample. In the limit a factor might happen to retain exactly the same value through the various individuals of the sample. That is, some of the linking factors do not in reality come into action, or not in their full force. (b) On the other hand, some factors which are really different and unconnected may happen by chance to rise and fall together, throughout the sample, and more or less to act as one. That is, fictitious linking factors are created, which would disappear with a larger sample.

Clearly therefore a hierarchy of correlation coefficients, caused by sampling the population, is due to chance having caused a change in the apparent factors acting. It follows that if we make a real change in the factors acting, we shall get a hierarchy, and this is what we do when we choose the mental tests to be employed in any research. Each mental test is a test of a sample of abilities.

The laws governing the correlation of correlation coeffi-

¹ Godfrey H. Thomson, *Proc. Roy. Soc. London*, 1919, A, 95, pp. 407 and 408.

cients which vary because of sampling the population can, in fact, be applied without hesitation to the relationships between 'true' correlations in the whole of any population simply because any such population is itself a sample. English grammar school boys of 12 are themselves a sample of a larger boyhood; the whole human race indeed is a sample of 'what might have been,' selected by the struggle for survival.

The whole question clearly has philosophical bearings on the degree of reality of causal connections; for on this view those chance links in a small sample which were a few paragraphs ago termed 'fictitious links, which would disappear with a larger sample,' do not differ except in degree from the 'real' causal links which we only term real because they persist throughout the largest sample with which we are acquainted.

In another direction there are connections with the difference, which is one of degree only, between what is called 'partial' correlation and 'entire' correlation.¹

The conclusion to be drawn from this section of the present paper is that hierarchical order is the natural order to expect among correlation coefficients, on a theory of chance sampling alone, and that therefore, by the principle of Occam's razor, its presence cannot be made the criterion of the existence of any special form of causal connection, such as is assumed in the Theory of Two Factors.

V. A SAMPLING THEORY OF ABILITY

In place therefore of the two factors of that theory, one general and the other specific, the present writer prefers to think of a number of factors at play in the carrying out of any activity such as a mental test, these factors being a sample of all those which the individual has at his command.

The first reason for preferring this theory is that of Occam's razor. It makes fewer assumptions than does the

¹ See Karl Pearson, 'On the Influence of Natural Selection on the Variability and Correlation of Organs,' *Phil. Trans. Roy. Soc. London*, 1902, A, 200, pp. 1-66. Godfrey H. Thomson, 'The Proof or Disproof of the Existence of General Ability,' *Brit. J. Psychol.*, 1919, 9, pp. 321-336.

more special form of theory. It does not deny general ability, for if the samples are large there will of course be factors common to all activities. On the other hand it does not assert general ability, for the samples may not be so large as this, and no single factor may occur in every activity. If, moreover, a number of factors do run through the whole gamut of activities, forming a general factor, this group need not be the same in every individual. In other words general ability, if possessed by any individual, need not be psychologically of the same nature as any general ability possessed by another individual. Everyone has probably known men who were good all round, but Jones may be a good all round man for different reasons from those which make Smith good all round.

The Sampling Theory, then, neither denies nor asserts general ability, though it says it is unproven. Nor does it deny specific factors. On the other hand it does deny the absence of group factors. It is this absence of group factors which is in truth the crux of Professor Spearman's theory, which is not so much a theory of general ability, or a theory of two factors, as a Theory of the Absence of Group Factors. And inasmuch as its own disciples have begun to require group factors to explain their data, its distinguishing mark would appear in any case to be disappearing.

Such group factors as are admitted by Professor Spearman are of very narrow range, and are mutually exclusive, that is they do not overlap. Both these points follow from the sentence used in the 1912 article with Dr. Hart, where it is said that, in the case of performances too alike, 'when this likeness is diminished, or when the resembling performances are pooled together, a point is soon reached where the correlations are still of considerable magnitude, but now indicate no common factor except the general one.'

Since this point is soon reached, the group factors must be narrow in range. Since pooling a few performances will obliterate any group factors, they must be exclusive of one another. For if *A*, *B*, *C* and *D* are four tests, in which *A* and *B* have a group factor common to them, and *C* and *D* another,

then of course by pooling *A* with *B* and also *C* with *D* we can obtain two pools *AB* and *CD* which have no link. But if *A*, *B* and *C* have one group factor, and *C* and *D* have another then these group factors cannot be separated into specific factors. In fact, a specific factor is a separated group factor, and Professor Spearman's theory asserts that group factors, if any, are separable and mutually exclusive. This is to the present writer the great stumbling block in the way of the acceptance of the Theory of Two Factors, unless 'specific factor' is interpreted in the way suggested later in this article.

It is a fact which will be admitted by most that the same activity is not performed in the same way by different individuals, even though they are equally expert. Not only are specific factors therefore required by this theory for every separate activity, excluding only any which are very closely similar; but also specific factors of different psychological natures are required for each individual. Further, the same individual does not always perform the same activity in the same way. A man using an ergograph will, as he tires, begin to employ muscles other than those naturally used at the outset. When we are returning from a cycle ride muscles are used in a different manner from the style adopted at the start, indeed sometimes deliberate changes are made to give relief. And in the same way a mental task is performed by different methods at different times. Does this then mean a different specific factor for each way of doing a task? All these difficulties appear to argue against the Theory of Two Factors, and seem to the present writer to be considerably cleared up by the Sampling Theory.

Finally, the Sampling Theory appears to be in accordance with a line of thought which has already proved fruitful in other sciences. Any individual is, on the Mendelian theory, a sample of unit qualities derived from his parents, and of these a further sample is apparent and explicit in the individual, the balance being dormant but capable of contributing to the sample which is to form his child. It seems a natural step further to look upon any activity carried out by this

individual as involving yet a further sample of these qualities.

VI. THE DIFFICULTY OF 'TRANSFER OF TRAINING'

Although Professor Spearman's Theory of Two Factors has been chiefly based by him on the line of argument which, it is suggested, has now been proved invalid, viz., the 'hierarchy' argument, yet there is another and powerful form of reasoning which can be brought up to its support, based upon the fact that, according to some experimenters, improvement in any activity due to training does not transfer in any appreciable amount to any other activity, except to those very similar indeed to the trained activity. And even those workers who do not agree that this is an experimental fact are usually content to take a defensive attitude and say that transfer is not disproved. Few if any will say that it is proved.

This certainly seems to point to the absence of group factors, and to support Professor Spearman's theory, which only needs to add to itself the assumption that the specific factors are, while the general factor is not, capable of being improved by training, to fit the case admirably. Of course, if transfer really occurs, the argument proves the opposite. And although psychological experiment points on the whole to the absence or the narrowness of transfer, yet popular opinion among business men, schoolmasters, and others is in favor of transfer to a considerable extent. Assuming no transfer, however, how can the Sampling Theory, with its numerous group factors, explain this?

It is necessary to assume that the group factors are all unimprovable or only slightly improvable by training, though they may change with the growth and development of the individual. The improvement which certainly takes place when we practice any activity is due, it may then be assumed, not to improvement in the elemental abilities which form the sample, *but to a weeding out*, and selection of these. The sample alters, mainly no doubt is diminished, though additions are also conceivable. It becomes a more economical

sample, and waste of effort in using elements which are unnecessary is avoided. Improvement in any mental activity may on this view be compared with improvement in a manual dexterity, in which it is notorious that the improvement consists largely in the avoidance of unnecessary movements.

When another activity is then attempted, the elemental factors are just the same as they would have been had the practice in the first activity not taken place. The new activity will be performed by a new group of factors, which sample will as in the first case be in the beginning wasteful and will include many unnecessary elements. Transfer of improvement gained in the first activity will therefore not take place except insofar as the second activity is recognized as a mere variant of the original one, in which case the weeding out process which has taken place in the first case may be done at the very first attempt, at any rate to some extent.

To use another analogy, the improvement which takes place when a football team practices playing together for a series of matches is due more to team work than to individual improvement. A new team, even though it contain a large proportion of players from the first team, will not have this unity of action. There will be little transfer of improvement.

According to the view here developed, it is the weeding out of the sample of elemental abilities which is specific. The team work is specific, though the players play for several clubs. This would appear to enable a reconciliation to be affected between the almost universal belief in 'types' of ability (to which Professor Spearman refers) and the experimental facts concerning both correlation and transfer. If there be a general factor at all, it might be the power to shake down rapidly into good team work, in a word, educability. But there seems no objection to assuming that this, instead of being a general factor, is a property of each elemental factor, varying from factor to factor.

To sum up this section: if transfer of training really does not occur to any great extent, then it has to be admitted that

the Theory of Two Factors readily explains this. But the Sampling Theory can also do so, in a manner which is perhaps not so easy to set forth, but which nevertheless appears to the present writer to be more illuminating and less artificial than the alternative theory.

VII. THE 'FACULTY FALLACY'

Since the group factors spoken of in this Sampling Theory are, in the fact that they are supposed to come into play in many different activities, similar to the banished 'faculties' of the mind (though the writer conceives of them as being smaller units than were those faculties) it is probably necessary to defend the theory against the charge of committing what is known as the 'Faculty Fallacy.' This defence is easy. It is only necessary to point out (*a*) that a person who believes in 'faculties' or 'types' or 'levels' does not necessarily commit the above-mentioned fallacy, and (*b*) that any charge of being 'faculties' which may be brought against the group factors can of course also be brought against the general factor.

The clearest account of the faculty fallacy known to the writer is given in the older edition of Professor G. F. Stout's 'Manual': "An effect cannot be its own cause, and cannot, therefore, afford its own explanation. But it is a fallacy of not infrequent occurrence to assign as a cause what turns out on examination to be only the effect itself, expressed in different language. . . . The classical instance of this confusion is the answer of Molière's physician to the question: 'Why does opium induce sleep?' 'Opium,' he answers, 'produces sleep because it has a soporific tendency.'"

Now it is to be clearly noted that there is no logical objection to the physician saying either that opium produces sleep, or that it has a soporific tendency. All that he must avoid doing is to give the one as the cause of the other. And in a similar way there is no logical objection to anyone believing, on the ground of experiment, that if a man has a good memory for historical matters he will, as a fact, have a good memory for all other matters. But if he believes this

without any other ground than that the name memory is given to these diverse activities, then indeed he is committing the fallacy in question. Even if a man uses the form of words: "Robinson will be a good man for this post, because he has a good memory," he is not necessarily committing any logical fallacy. He may very well mean by this short statement something like the following: "I have noticed that a man who remembers one class of facts well is also frequently good at remembering other classes of facts. I know that Robinson can remember such and such things easily and accurately, therefore I think it very probable that he will be above the average in this job, which requires the memorizing of certain facts." And in this there is no fallacy, whether the conclusion be true or false.

The existence of the group factors spoken of in this paper is deduced with more or less probability from the known experiments. Their existence is an hypothesis which explains these facts, though it is not the only hypothesis to do so. If, as is very probable, the language used in any part of this paper is open to an interpretation which would involve the fallacy, then it can only be said that this is not the interpretation which is intended.

VIII. CONCLUSIONS

Professor Spearman's Theory of Two Factors, which assumes that ability in any performance is due to (*a*) a general factor and (*b*) a specific factor (group factors being absent, or at any rate very narrow in range and mutually exclusive) is based chiefly on the observed fact that correlation coefficients in psychological tests tend to fall into 'hierarchical order.' It has been shown, however, that the criterion adopted for evaluating the degree of perfection of hierarchical order present is untrustworthy and has led to overestimation. Such hierarchical order as is actually present is in fact the natural thing to expect, and it is the absence of such which should occasion surprise. The proof of the Theory of Two Factors which is based on the presence of hierarchical order therefore falls to the ground. The theory remains a possible

explanation of the facts but ceases to be the unique explanation. As an alternative theory there is here advanced a Sampling Theory of Ability, in which any performance is considered as being carried out by a sample of group factors. This theory is preferred because it makes fewer and less special assumptions, because it is more elastic and wider, and because it is in closer accord with theories in use in biology and in the study of heredity.

SUGGESTIONS TOWARD A SCIENTIFIC INTERPRETATION OF PERCEPTION

BY J. R. KANTOR

University of Chicago

Much of the criticism directed toward the results of psychological investigation might serve as a direct challenge to psychologists to clarify their interpretations of psychological phenomena; for a study of those criticisms amply reveals the bizarre views attributed to psychologists. Although this peculiar situation obtains with respect to all psychological descriptions, it is especially striking in the case of perception. Thus, a recent writer¹ finds it necessary to point out that an object is not merely a thing which 'starts a chain of vibrations which eventually results in its own creation.' To the present writer this specific criticism does not really call for a defense of the psychologist's position, since the critic holds substantially the same view as most psychologists, but the very fact that a writer will find much to criticize in any one who supports a similar doctrine is a symptom of a confusing situation which demands at least a restatement of perception.

Naturally enough the confusions mentioned reach deeper than the mere matter of exposition and in fact arise directly from the types of conceptions held concerning the process under discussion. A careful reading of psychological literature on perception creates the suspicion that the descriptions fail to tally with the actual facts in the case. As a striking example we find that perception is described as in some sense a creative process which functions in the organization of the discrete qualities constituting the objects of our reaction. In effect, we find practically all current perceptual doctrines very strongly reminiscent of Berkeley's subjectivism albeit modified somewhat à la Reid; the latter modification results in the view that there exists a percept as well as an object of percep-

¹ J. B. Pratt, *J. of Phil., Psychol., etc.*, 1919, 16, 596 ff.

tion. Psychologists cannot but consider the problem of perception as crucial, since the admission of a non-scientific subjectivism at this point will bring disastrous consequences into the entire science of psychology. In this article the writer attempts to suggest a description of perception, which, so far as it goes, consistently complies with the rigorous canons of natural science.

I.

General Description of Perception.—Perception is the conscious behavior through which are developed the meanings of objects and relations which operate in the adaptation of the individual to his surroundings and in the control of them. It is precisely in the process of perception that the individual, in direct contact with objects, develops reaction patterns enabling him to differentiate and distinguish the various objects affecting him.

At the outset it must be noted that the act of perception¹ is an adjustmental reaction, an actual interaction of one natural object with another. But the precise difference between this kind of interaction and some other is, namely, that one of the interacting objects is a psychophysiological organism to whom the results of the present interaction will become significant in influencing future contacts of this object (person) with the same or a similar object. Consider, that what was formerly a mere interconnection between objects becomes what we might now call a knowledge process because the reaction becomes a means to some other form of reaction; that is to say, the first natural contact with an object is the basis for the development of an anticipatory reaction system. If the person is once burned, the object which produces this effect will upon a future occasion stimulate a touch inhibition reaction rather than a touch response. An empirical fact it is, there-

¹ While the writer is in complete sympathy with Watson in his revolt against subjectivism, and in his assertion that functional psychology is just as guilty in this respect as the structural view, he cannot assent to Watson's implication that perception among other processes is not properly the subject matter of a non-subjectivistic psychology. Nor indeed does Watson omit perception when he is interested in "integrations and total activities of the individual." His rejection of the terms is obviously to allow room for a predominantly physiological tone to his discussion.

fore, that all developed¹ perceptual responses operate as knowledge reactions, for in this way only do we learn to discriminate between objects, and to anticipate the specific response we should make to a particular object. But it is of extreme importance to notice that the perceptual reaction is not in its primary occurrence a knowing. To overlook this fact is to fall into the error of finally resolving the objects of our reactions into knowledges of some sort, and the history of psychology stands to witness that on the basis of such premises we invariably land in a mentalistic world in which objects are reduced to sensations, and the world of fact and science disappears in our description.

Only upon the assumption that the perceptual reaction is a natural psychophysiological response, the writer submits, can we achieve a natural science interpretation of the development of discriminative meanings. By thus investigating all the components of an act we may hope to obtain a scientific description of the total response and escape the arbitrary and confusing concept of a mental content, which is an unavoidable consequence of the presupposition that perception is a knowledge process.²

We must, then, look upon the perceptual reaction as a complex adjustment from which is derived the significance of objects through the integration of reaction patterns. This meaning of objects we shall see may be resident in the response pattern, or it may be more remotely connected with it, even to the point at which the act is no longer a perceptual but a conceptual reaction; in the latter case we observe that the meaning is detached from any overt act, and as a matter of fact we find that such detached meanings constitute the implicit functioning of the original reaction which ultimately generated the conceptual meaning.

Primary Perception and Simple Apprehension.—Upon the basis of the specific operation of meanings we may distinguish two definite forms or degrees of perceptual response which we

¹ Note the distinction drawn between perception in development and perception in use on another page of this paper.

² Expressed in the statement that perception is the consciousness (awareness) of an object present to sense.

will call primary perception and simple apprehension. In the former case, the meaning of the object responded to resides within the reactional movement of the person,¹ as illustrated by the perceptual process of an instinctive act. The meaning of a 'danger' object for the person is merely the startled jump which constitutes the operation of a connate reaction pattern. It must be observed that in this situation the neuro-muscular and neuro-glandular factors in the response are very prominent, and as a record of fact, the cognitive component merely consists of a simple appreciation of the presence of the stimulating object.²

In simple apprehension the meaning becomes more and more detached from the immediate condition of response. Instead of the mere presence of an object calling out a specific reaction, the object may serve as a symbol for some action. In consequence, the discriminated significance of the object will be attached not to the direct movement as in primary perception, but to another response which is to follow. Evident it is that a meaning of this type is an implicit response in the form of an anticipatory process similar to that we invariably find as an important factor in all delayed responses, whether simple acts or chains of acts. This capacity to detach meanings gives the person a greater control over the objects of his environment, for, if the meaning of the object is appreciated before an overt response is made, the type of response can be widely varied between limits.³ In contrast to primary perception the meaning in simple apprehension is always correlated with an awareness-attention process.

Implicit perception functions in adaptational situations in which there are more definite appreciations of the surrounding objects. We might take the case of meeting a friend in which there is a complete and definite meaning element. Consequently the overt action which takes place is more conditioned

¹ We might just as well say the meaning is in the object, but it is clear that unless there is an action involved the problem even of the location of meaning does not arise.

² The components spoken of are, of course, abstracted from the actual response by logical analysis.

³ Cf. my brief suggestion concerning the detachment of meanings, *PSYCHOL. REV.*, 1919, 26, 2 ff.

by the meaning component. If he is an American friend, I may merely shake hands with him, but if he is a foreigner, I will probably also raise my hat and bow. Clearly the entire course of my behavior in this situation presupposes my familiarity with the person. It must not be overlooked that we do not exclude from our description of simple apprehension the simpler immediate reactions which occur in primary perception. For the fact is, that since simple apprehension is always the development of an act of primary perception, it involves therefore an integration of the simpler acts. Of prime importance here is the fact that it is precisely through the integration of the simpler acts that a person profits by past experience. For instance, my reaction to this person is conditioned by the numerous integrations of responses representing my previous contacts with him.

Thus through the constant growth of the reaction pattern does the perceptual process undergo a continuous development. Not only does a given response serve at any specific time as an adaptational function, but also as a developing potentiality for some future contact between the person and the object.

Analytic Description of Perception.—Although the perceptual response is a thoroughly organic process, we can nevertheless analyze it into a series of specific stages or act components which we can tabulate as follows:

1. The attention function in correlation with contact media (light rays, for example).
2. Functioning of a reaction pattern which involves
 - (a) Discrimination and appreciation of specific qualities and relations of objects coupled with conative and affective factors.
 - (b) Neuro-musculo-glandular processes.
3. Emergence of meaning (new).
4. Overt adaptation follows.

1. The attention factor is the selective process which serves to prepare the individual for a new reaction. At any moment of time innumerable possibilities for action naturally exist because of the previous acquisition of many reaction systems. The change in the surrounding medium or media of the person,

which occurs when the individual comes into the presence of new objects, or when objects change their positions with respect to the person, puts him into a condition of readiness to react to some new object. It must be observed that the attention processes depend not only upon the stimulating object and its setting, but also upon the condition of the organism at the time, that is to say, the selection process depends very directly upon what the activities of the person were prior to the present contact. Such activities condition also what precise phase of an object we will react to at a given time. Thus, for example, the problem as to why at one time our attention is attracted to a red solid instead of a smooth surface, when both form the phases of a book, is solved by an investigation of the previous activities of the person.

2. Following the selection function, the reaction pattern is brought into activity, and we find thus a highly coördinated series of processes taking place. These may be enumerated separately, although they constitute merely descriptive phases of a unitary process. Here we find the discriminative process which enables the organism to distinguish the various qualities and relations of things. This phase may be thought of as the cognitive aspect of the reaction system, and to a degree we may look upon this phase as conditioning the mode of operation of the entire complex. The conative factor in this complex, being very closely connected with the attention function, may be considered as the aspect which conditions the occurrence of a response at all. Of primary importance are the affective processes, which in part predispose the organism to act. Every reaction pattern involves of course also the elaborate functioning of musculo-neural and neuro-glandular processes, which are so prominent as to convince some observers that they constitute the total reaction pattern.

3. As a result of the operation of the reaction pattern a new effect is or may be produced upon the organism. Should the object or person reacted to, with all the involved relations, remain constant, no new reaction is called out; that is, the previously developed reaction pattern remains unmodified despite the present contact. The object, then, will not take

on any new meaning and the overt act following the appreciation of the identity of the object may be precisely like one that has previously occurred. We can readily determine this to be the case of perception in use. On the other hand, should the previously developed reaction system prove inadequate for the purpose of the present contact, new features may develop. Instead of involving some given system of receptors in connection with certain neural and muscular processes, additional factors may be put into operation. Thus, for example, should the apple previously sound and firm to touch now offer no resistance, it will call out different muscular responses. Similarly, should it now present color surfaces varying in hue, turning from red to brown, the object will take on new meaning, and we will react in a different way to the now deteriorated apple. Thus, indefinitely many modifications are developed in the course of the exercise of so intricate a psychophysiological response pattern.

4. Following upon the operation of the definitively perceptual reaction system, the person performs some sort of overt act. The latter is directly conditioned by the emergence of the meaning brought out through the course of the specified contact with the object. It must be observed that the specific perceptual process is a coördinate process with some other type of reaction system. Thus, we should look upon the perceptual function as a part of a perceptual-instinct, perceptual-emotional, or perceptual-voluntary action, etc. To look upon it in this way obviates the dangerous view that in the actions mentioned we have isolated activities. As a preliminary or partial action the perceptual process represents an evaluation of the object which leads to a definite overt response. It is at this point that the perceptual reaction becomes a knowledge function, since it stands for some actual adjustmental act. Whether the apple of our illustration will be eaten, or thrown away, depends upon the information elicited through the operation of the perceptual reaction system and its modifications. At this point, we must not overlook the fact that the appreciation of an edible or non-edible meaning depends upon the surrounding conditions of the object. Even

if the knowledge elicited from the object itself is favorable to its consumption, that event will not occur unless conditions are otherwise favorable. We mean to point out here that the specific kind of response patterns that will act as a series in any given situation will depend upon that situation. This fact indicates the close interaction between stimuli and responses.

An important reservation to the above description of the perceptual activities must be made in the light of our distinction between primary perception and simple apprehension. It is only in the case of simple apprehension that the distinct series of factors are found; for it is only there that a definite meaning factor is isolated in the total act. In primary perception the overt act is identical with the original system, and the perceptual process itself constitutes not exclusively a definite knowledge factor in an adjustment, but it is the whole adjustment itself.

Perception in Development and Use.—Of primary importance for the understanding of the perceptual reactions is the distinction between perception in development, and in use. In the former type of reaction with objects meanings are developed; that is to say, a definite form of reaction pattern is acquired; so that the future contact with this object will be of a definite and peculiar sort, because the reaction pattern developed will then be put into use. The distinction made indicates the extremely complex and constantly varying character of the perceptual reactions and points to the mechanism of elaboration of such functions.

Since clearly the original perceptual contacts with objects occur in the instinct stage of development, we may date the origin of a meaning or reaction pattern from the first instinct contact of an organism with any given object. The point is, that the hypothetical, original contact of an organism with an object is the result of a direct arousal of a connate reaction pattern through the instrumentality of various physical media such as light rays or air waves. If we dare speak of a meaning possessed by an object at this stage, it is merely that of 'response eliciter.' This contact is as mechanical as a conscious

behavior act can be, and here we find the full significance of the statement that we have innate tendencies to discriminate colors and other physical qualities. The fact is that our connate reaction patterns are brought into function by the stimulation of the specific receptor systems whose activities form a part of them. At this stage the simple psychophysiological response as a whole, symbolizes the meaning of the object. Now, when the action just mentioned occurs, some effect will be produced upon the organism; so that the next contact with this object will involve a modified reaction system, or we might say, the object has taken on a new meaning. The perceptual processes thus represent a constant integration of a reaction pattern depending upon the number of contacts with the same physical object under varying conditions of surrounding auspices. In general, it is clear that the perceptual reactions are entirely genetic in their functioning, hence only by studying them in their development can we hope to understand them.

Another form of integration in the development of perceptual reactions is the establishment of a definite interactional relationship between the stimulating object and the reaction system. Not only must there be a coördination of specific factors of a response system, such as for example, visuo-muscular, visuo-glandular and neuro-muscular processes, but there must also be a connection between this total reaction pattern as a functional representative of the organism at the time and the stimulating object.¹ Just how this intimate relationship between stimuli and response systems, which is the essential factor in perception in use, is established, can be experimentally studied through various types of conditioned reflexes. Excellently is perception in use illustrated by the story of the discharged veteran, quoted by Spencer, who had had the auditory object 'attention' so integrated with a particular response system as to lose his pie when a practical joker uttered the command.² When the integration has been accomplished, the reaction pattern can be stimulated by one or more of a large series of phases of the object, which become

¹ This connection between the response pattern and its simulating object constitutes the primary and fundamental type of psychological association.

² 'Psychology,' I, p. 499.

differentiated because of the different media through which the contacts between the organism and the objects are made. Thus, a reaction pattern involving a ball-meaning may be put into action by either a visual, auditory or tactual stimulus. As an illustration of the arousal of a complex system of perceptual responses through the mediation of a simple type of stimulus, we can take the case of the visual contact with ice, which arouses coldness, smoothness and hardness meanings at the same time. The effective adaptation of the organism depends to a considerable degree upon the complexity of the two sorts of integration described.

Because perception in use as just described involves putting a complex reaction pattern into operation by some phase of an object, we find in such adjustments the beginnings of a differentiation between the explicit and the implicit functioning of a reaction system; the latter case gives us the detached meaning. The implicit functioning of a reaction pattern is clearly discerned in the many cases in which the visual contact is the only direct one; and the meaning of the object, which may be very elaborate, though not attached directly to an immediate response, is most certainly acting. A striking example of the implicit functioning of reaction patterns is the situation in which a banker, while otherwise preoccupied, for a moment will begin to respond as though at a director's meeting, when stimulated by the crumpling of a crisp paper. Again, the 'wave of feeling' brought on by the perusal of a literary description indicates the living over of some crucial situation by the incipient operation of reaction systems. It is this implicit functioning of reaction patterns in perception which shows the way toward the development of the conceptual and memorial processes.¹

From our description of perception in development and in use it must appear that these are not two distinct operations, but rather two mutually interrelated processes. Since the perceptual activities are constantly developing we have in practically every new operation of a perceptual reaction system

¹ As a matter of fact, so far as psychophysiological mechanism goes, there is only a difference in degree between perception and thought, but from the standpoint of results effected through these reactions the variation is or may be enormous.

a more complex integration of the component action elements with the stimulating situation. If we consider the perceptual reaction as the use of meanings stimulated by direct contact with objects, we find that the distinction between the development of perception and its use, depends upon the amount of direct stimulation which is required to elicit the response. Perception in development requires a relatively larger series of direct contacts to effect an equally complex response than is true in the case of perception in use, since in the latter case the meaning attaches to an incipient reaction pattern. We repeat, the development of perception is a process of so integrating acts that only a minimum of receptors may be necessary to effect the appropriate response. If we remember that this development never ceases, provided that we have occasion to react to the given stimulating object, then it is clear that perception in use is merely the condition of responding on the basis of a previously acquired reaction system, pending its modification by the present contact with the object in question.

The Specific Mechanisms of Perception.—A more penetrating analysis of perception than we have yet made will yield information as to the specific integrations which operate in the perceptual reactions. To a certain point we can trace the precise organization of the component processes, such as the muscular, cognitive, glandular, neural, etc. Our ability to do this is made possible by the fact that underlying all these modifications is a simple psychological law which may be formulated as follows. *Every integrative modification of a reaction pattern is a direct function of a differential contact with actual things.*

By far the most important problem of perception arises just here, namely, what are the specific means of contact between the organism and objects? The interest in this problem emerges because of the inevitable incorrect inference from the customary psychological premises, namely, that the cognitive qualities are existential processes somehow aroused in 'consciousness' which bring about the movements of the organism. Now as a matter of fact, it is easily seen that in any description of perception the qualities mentioned (odors, colors, etc.) are

abstracted from the objects. The discrimination of these qualities as it occurs in the actual response is in part the perceptual act; that is to say, the discriminative process constitutes part of the perceptual act as distinguished from the overt action which follows it. The discriminative factors are thus seen to be phases of concrete psychophysiological processes, and this means in effect the total extrusion from the perceptual act of any substantial mental or subjectivistic quality.

Responsible for the view of the existence and primary functioning of sensation qualities, is the psychological tradition which makes knowledge the differentia between biological and psychological acts. Taking conscious behavior as our starting point, we may catch a glimpse of the true significance of the perceptual reaction as a knowledge process which brings about adequate, psychological adaptations, and still keep our descriptive analysis of the facts within the range of observational interpretation. The favorable prognosis for the scientific development of psychology depends in large measure upon the rejection of a theory implying that the adjustmental responses of the individual are due to a mystic potency resident in 'consciousness.' In place of such a theory should be substituted a verifiable interactional mechanics of natural things. Upon the basis of such an interactional mechanics it is possible to avoid the assumption that perceptual responses are primarily cognitive operations or that they are 'consciousness,' that is to say, awareness of something, rather than adjustment acts.

Thus, the problem of the contact of the individual with objects is reduced to the description of the precise manner in which a reaction pattern or system is put into operation by the stimulating object. Here we have to assume that the reaction is that of a conscious organism, which has the capacity to react to colors and other qualities. As a matter of fact, the notions we have of such qualities are historically developed through the discriminating evaluations of such conscious beings. Now, although it may be impossible to develop a detailed analysis of all that takes place in a perceptual reaction, we can

isolate series of systems which play their part in such reactions. These systems are logically ordered sequences of events which occur when a perceptual reaction is made. An example of one of these systems is the cycle beginning with the reflection of light rays of definite sorts which set up differential processes in the retina, followed by definite happenings traced out in the neural pathways and in the cortical areas of the brain. The completion of the cycle involves the consideration of changes taking place in the association tracts and the motor localities of the cortex, the happenings in the efferent transmission system and in the effectors located in muscles and glands.¹

Of extremely great consequence is the series of appreciative and feeling processes which are factors in the operation of the total reaction system under discussion. The important point here is that the perceptual reaction must be looked upon as one of the ways in which a psychophysiological machine is operating. Above all, what we wish to avoid is the conception that the physico-neural functions constituting part of the perceptual act, are the causes or the parallels of conscious action. A very simple means to avoid this confusion is to remember that we are dealing here with two phases of a natural happening which for scientific purposes are differently classified, but never separated, and also that no process is any more tangible than another. Physical processes are not tangible physical substances, nor are the physiological factors biological material; neither are both of these functions absolutely distinct from the mental processes which naturally do not reduce themselves to mentality, a substance the existence of which we all join in denying. What we must describe here is a psychophysiological reaction, for it is only such a reaction which can be the object of our observations. While observing

¹ The reader who is interested in a more detailed discussion of the mechanisms of conscious behavior is referred to Watson's recent volume, 'Psychology from the Standpoint of a Behaviorist,' which contains the best description in psychological literature of the behavioristic components of a reaction system. Because of the author's resolute attempt to suppress the mentalistic components of the reaction pattern, the book contains merely suggestions, though frequently very important ones (especially in the chapter on Emotions), concerning those phases of a conscious response.

a psychophysiological organism we can discriminate between acts involving a response pattern of predominantly mental factors and others having the physiological factors more prominent. It is the former type of psychophysiological act which is usually called subjective, and which is in part responsible for the inexcusable separation of the mentalistic and behavioristic phases of a unitary act.

Since we can analyze many of the isolated factors of a perceptual reaction we can describe specific correlations between the qualities of objects and the particular phases of the reaction pattern. Thus colors, sounds, tastes, hardnesses, etc., can be coordinated with specific receptor systems, because during the evolutionary development of the organism the receptor systems became differentiated in sensitivity to particular kinds of stimuli, which objects initiated. For example, the retinae are normally sensitive only to light rays reflected by the colored surfaces of objects, and the cochlea to air vibrations, which emanate from sounding bodies. In passing, we might point out that our analysis has provided no basis for the assumption that 'objects as perceived' are synthesized in some form out of qualities produced in the mind or in the organism by stimuli set up by objects. After many detours this view just mentioned has seeped into current psychology from the Berkeleyan head waters, and for a long time has been effective in preventing the conception of psychological phenomena in a scientific way. In contrast to the Berkeleyan view, we must look upon the stimuli which constitute the middle link between objects and organisms as natural predisposing conditions, mediating changes in the activities of the latter, much after the fashion in which an electric current produces changes in a machine. The undesirable consequences of thinking that in perception there is a synthesis of objects is well illustrated by the conception that space and time are somehow compounded by some additional attribute of the mental 'contents' called sensations.

The Relational Character of Perception.—Observations upon the perceptual interaction with things convince us that not only are all perceptual reactions not merely responses to specific

qualities, but also that they are not confined to isolated objects; they are more than either of these descriptions indicate, namely, responses to a complete object in all its setting. We might generalize this fact by saying that we always perceive situations, not isolated things, and of course our conduct is conditioned accordingly. Thus a chair which ordinarily would be responded to by being sat in, will not call out such a response when it is occupied by some object or when there are individuals present before whom it is impolite to make such a response. In every such case the meaning of the object will depend upon the contextually related objects. When the chair itself is reacted to, we respond to a unified object, and not to simple elements (back, seat, legs, etc.); that is to say, we react to an object to-be-sat-in, and not to isolated fragments which require to be somehow connected. This relational character of perception is excellently illustrated by our responses in which words and not letters are the stimulating objects, and in which the words are directly and inseparably attached to other words.¹

That we can immediately appreciate a complex situation apparently comprising many diverse elements is owing to this relational character of perception. Thus, in looking at a landscape the objects all seem to be in their proper places; distances are correctly located and the lights and shadows properly distributed. The total situation is the customary object of our reactions and is thus the stimulus to a unified primary response or simple apprehension. The meaning of the total situation can be readily and completely confounded by placing ourselves in a position incapacitating us for response, such as looking at the landscape with our head upside down. Much the same effect is produced by looking at an inverted painting. In such situations what happens is that the series of integrated reaction systems are thrown out of their customary harmonic organization and must be reorganized before the object can be correctly perceived. Experiments on space perception have shown that

¹ James points out with his characteristic description the unnatural aspect which a word takes when looked at in protracted isolation. "It stares at him from the paper like a glass eye with no speculation in it. Its body is indeed there, but its soul is fled." 'Princ. of Psychol.', Vol. II., p. 81.

by practice disorganized response systems can readily be reintegrated.¹

The difference in the responses to objects when they appear in different contextual relations illustrates the extremely subtle interaction between the stimulating object and the reacting person, and also shows the operation of perception as an adjustmental reaction to surrounding objects. Pliability of the individual in this sense constitutes an important factor of general intelligence and exemplifies the law of integrated modifications of reaction systems mentioned above.

The Interpretative Function of Perception.—Since every psychological phenomenon is a product of two factors, namely, the stimulus and the response, our discussion of the influence of the stimulating circumstances upon our perceptual reactions naturally leads to the consideration of the influence of the individual's stock of reaction patterns upon any given present reaction. An observable fact it is, that the reaction systems which the individual has developed in his constant contact with objects, play a large part in any present reaction; for in a genuine way such reaction patterns constitute the individual at the moment. And since as we have indicated, these response patterns have been developed in the individual's previous experience, every perceptual reaction may be thought of as an interpretative function. In effect, this means that the person will respond to objects much as he has been accustomed to do under previous conditions of contact with similar objects. It is this fact which gives origin to the idea that perception is a kind of habit.² Being equipped with a response system to react to stimulating objects, is fundamental as a condition of every recognition behavior. The element of novelty comes into a response situation precisely at the point at which the person is unable to offer a complete response to the present stimulating object. Since the meaning of the object is not fully comprehended the person can respond in a way which is only a partial reproduction of a previous form of response. The lack of complete recognition means that the person is not

¹ Cf. Stratton, *PSYCHOL. REV.*, 1897, 4, 341-360, 463-481.

² Cf. Angell, 'Psychology,' 1910, p. 157.

supplied with a reaction system to respond immediately to the object in question. In such a case the pressing need for a response to the object results in an incipient trial and error process ending in a clear-cut appreciation of its meaning and a consequent thinking reaction.

The interpretative function of the perceptual reactions is observable in many instances of daily occurrence. In the case of reading and speaking we find that there is very little stimulating material, but the response is not at all interfered with. In listening to a familiar voice, or familiar written material, we can easily demonstrate to ourselves that our response patterns are aroused by no considerable amount of excitation. No doubt the explanation for this lies in the individual's possession of dispositions organized for particular forms of situations and any prominent feature of those situations will set off the reaction patterns. It is here that we find the bases for the incorrect or unexpected responses commonly called illusions. For the same reason a person with a limited experience will be ready upon fewer occasions to respond to objects, and on those occasions will be slower to make the reaction. It has been aptly said,¹ that 'the artist sees details while to other eyes there is a vague and confused mass; the naturalist sees an animal where the ordinary eye sees only a form.' That the child reacts to objects in monotonously similar ways, is true because it has been impossible for him to build up many reaction systems. And so the significance of the pony and what can be done with it are the same as in the case of the dog, with only a variation in size. The classical illustration of the observable facts in this case is found in the name response (big dog) which the child makes to the pony.

The Elaboration of the Perceptual Functions.—The constant development of the perceptual response serves as one of the individual's important means for a growing mastery over his environment. As the reactions to an object multiply, that is, as the number of responses which it calls out increases, the object takes on more and more meaning. It is owing to this

¹ Lewes, 'Problems of Life and Mind,' 3d series, p. 107.

increasing elaboration of the perceptual response systems through the addition of meaning factors that the organism is enabled to make its way with greater facility through the maze of its surrounding objects. This facility is further increased by the fact that this elaboration of the perceptual response systems makes it possible for the person to adapt himself to many situations without invoking a definite problem of adaptation. Because of the absence of such a specific problem, and the consequent exclusion of a thought function, the simple form of the perceptual reaction allows for an immediate response to objects.

As a hypothetical illustration of the growth of the perceptual responses we might consider the reactions of a child to a typewriter. Allowing for a definite development already attained, the machine may be at first merely a thing which can produce a series of sounds when the keys are pressed. The machine, then, as soon as it is seen, has merely the sound-making meaning in the immediate response. With a more extended acquaintance with the machine the child learns that it can stimulate different and additional responses, and it thus has a different meaning when perceived. Finally, the machine takes on the complete set of meanings which are derived from all the responses the child can make to it. The point is, that what sort of perceptual reaction an object will call out at any time, or what it will mean, will depend upon the sum total of the person's contacts with the object in question. The perceptions of persons grow continually, and the growth depends upon the addition of new features to the response patterns and of completely new patterns of response.

The development of perceptions by the growth of responses is well illustrated when we are at the point of substituting an object for another in the face of an immediate need. Thus, a chair becomes a barricade, or step ladder, or typewriter table. As a consequence of the person's being forced to make new and unusual responses to objects, the latter become endowed with a range of new meanings. In the above illustration we also observe the active relating function as it occurs on the perceptual level. The similarity between objects is of course

a fundamental causative factor in the perception building activity, since otherwise the possible reactions to objects would be at such variance as not to admit of any correlation.

II

If the brief description of the perceptual reaction which we have essayed is correct, it obviates some of the most salient errors in current discussions of perception, and places the interpretation of such processes upon a definite natural science level. Let us first observe, then, that the perceptual reaction is always a reaction and not a thing, namely a complex organization of subjective qualities. Moreover, a perceptual reaction is a psychophysiological reaction as all data of psychology are. That is to say, the perceptual act is not in any sense the act of an ego, or mind of whatever description, nor of a nervous system, but a complex reaction system involving all the functions of a conscious being. Notice that the vexing problem of a self, vexing, that is, once it is allowed, plays no part whatever in the interpretation we have made above. For the sum of the reaction systems which adjust the individual constitute the person, and since each person because of his particular interaction with things and persons, has developed definite types of reaction patterns, the problem of character or personality is thereby solved. Since psychology is interested only in such reaction systems there is naturally a perfect co-ordination between psychology and the other sciences of the individual, such as anatomy, for example, which is interested in the structure whose functions form part of the reaction pattern.

That we cannot assume that in the perceptual act we have besides an object stimulating the organism, and the organism (frequently taken to be merely the nervous system) also an object of perception, that is, a sum of mental qualities, we indicate by the statement that there are only two interacting things in a perceptual as in any psychological act, namely, the organism and the physical object. The fact is that the physical object contains all qualities, colors, sounds, tastes, hardnesses which we can ever analyze out of it, and the organ-

ism learns to distinguish these and to name them because of specific psychophysiological effects which contact with objects brings about in organisms.

Our view may be illustrated by the following example. When we perceive a blue object, in no sense is there started up a 'consciousness' of blue by an antecedent or accompanying neural activity. As the matter is stated by practically all psychologists there comes to be at this point a blue consciousness or a blue sense quality. Now we maintain that the only blue involved is a blue object, independent of a perceiver and in no wise modified by the specific perceptual act; any change in the object must be effected by the overt action following the perception. What occurs in the above illustration of a perceptual act, is that the light rays set into function a complex reaction system which involves the specific meaning of this object, in the sense that the immediate effect produced by the object on the person may now result in a specific act, perhaps in the exclamation, 'I see a blue flower.' The effect upon the person, we repeat, is muscular, neural, glandular, cognitional and perhaps affectional. Let us remember that at this stage we must consider the activity as perception in use, which has developed through a series of previous contacts with the object; for otherwise many kinds of direct contacts besides those mediated by light rays would be necessary, in order to arouse so definite a meaning of the object as to be followed by a definite act.

Clearly, the specific perceptual act is an abstraction from an empirical interaction of a person and an object; that is to say, the perception proper is abstracted from the preceding and following acts of the person, while the object is abstracted from its setting which includes many other objects and persons. The description of a perceptual act is always a deliberate rationalization of a complex event, a fact which is at least implicitly recognized by all psychologists; even those who despite their Berkeleyan adherence to mental states agree that the perception of blue is an abstraction from a blue object (of perception).¹ This abstracting process can be made out

¹The writer refers here to the statements by psychologists that sensations are always abstractions.

most clearly perhaps by a thoroughgoing analysis of the development of the naming reaction performed in denoting things.

While it is almost impossible to describe so intricate an organic activity as a perceptual act, and at the same time avoid completely falling into a logical instead of a psychological analysis, it is still possible so to guard one's description as to prevent an essential misconception of the behavior. But unfortunately such misconstruction is rarely guarded against, for most analyses of perception merely amount to the isolation of the qualities of an object and the transformation of them into sensations, which in their totality are presumed to constitute the known object as over against the material object, which by hypothesis must remain forever beyond the pale of mental things.¹

At the basis of the current, primarily logical analyses of psychological phenomena which may be taken as symptomatic of the unscientific character of such description, lies the prejudice deep rooted, that psychology is the study of mental states, a kind of stuff (masked by the veil of process)² which is different from physical material. In no matter what form this subjectivistic view is presented it must be looked upon as a vestige of religious thought in psychological dress. Today, it must be rigidly extruded from scientific thinking, since it is a prejudgment of facts to be observed. On the contrary, genuine scientific thinking must start with observable phenomena, and naturally enough when we start in this way, we never meet with mentality or physicality as the psychologist deals with them.

The immediate development from this false dualism is that the domain of psychology is that of knowing, for consciousness is thinking stuff.³ Now thinking or knowing is assumed to be

¹ Sometimes the percept is considered as distinct from sense qualities as in the statement by Stout, "The general possibility of the transition from sense-impression to percept depends upon the existence of the percept as something distinct from the sense-presentation to which it seems as a rallying point and center of connection," 'Analytic Psychology,' Vol. II., p. 31.

² In spite of the veil no other interpretation is possible of a thing which has attributes.

³ The trend of modern thought as influenced by Descartes.

the most intangible and inaccessible stuff or process, and thus has arisen the esoteric psychology of introspection. Clearly there can be no science which has as its subject matter intangible and invisible subjectivistic states, and for this reason the history of psychology mirrors much groping about for some concrete material with which to work. Finally, psychologists seized upon the nervous system as a tangible basis for the intangible consciousness. In our own day the behavioristic movement at least in one of its phases assumes that it is really the nervous system with which psychology has to deal and not at all with consciousness. This behavioristic view, though clearly mistaken in that it is still based upon a dualism one phase of which is rejected, should be credited with much scientific acumen, since it must be taken as a protest against the obviously unscientific character of a mentalistic psychology. For no science can be built upon things or processes which are not observable.¹ When we consider a perceptual act as an adaptational response to some natural object, we find no necessity for the dual interpretation of psychological phenomena such as leads to the problem how a mental state can be made to know or refer to an external object. For the functional psychologist there can be no such problem; what he is concerned with is the way a definite sort of interaction takes place between two natural things, a person and some other object which may or may not be a person. Thus, the functionalist does not create for himself the question as to how a conscious state can be initiated by a previously or simultaneously occurring neural process.

Berkeleyan and Reidean influences in psychology are maintained by the confusion of the products of logical analysis and the concrete facts of conscious behavior. Thus, the relational and interpretative character of a psychophysiological reaction

¹ It is not to the point to argue as Stout ('Manual,' 1915, p. 18) does that 'mental dispositions' must be assumed to exist in the way that 'mass' and 'energy' exist, though not directly observable, for as he himself points out, physical things and processes are inferred from directly observable phenomena. This can not be said for his mental dispositions, which are not descriptive of actual facts. And furthermore, mass and energy are obviously useful categories of physical science, but mental dispositions are only necessary because of an erroneous subjectivistic interpretation of human behavior.

is assumed to be the growth of a mental state which is called a perceptual object. From this standpoint, animals and possibly infants are presumably supposed to have no perception because they cannot possibly have the knowledge which a human adult has. In detail, a perception is assumed to be a complex organization of sensation qualities with meanings attached. Thus meaning is further assumed to be the definite self-conscious interpretation of the sensation qualities, clearly an epistemological view. In contrast to the above view, we have already suggested that what occurs in nature is the building up of a reaction-system, which at first is simple, that is, the object has little meaning, and later further contact with the object complicates and expands the reaction system, which fact is interpreted as giving more meaning to the object by the increased number of possible reactions which can now be made to it.

The consequences of the view that perception is a mental structure, are clearly brought out in the issue raised by James¹ concerning the confusion of the object perceived with sensations or perceptions of the object. James saw clearly the fallacy of Stumpf's analysis of the sensation of oil of peppermint into the sensations of taste and temperature; for James would have it 'that we perceive that objective fact, known to us as the peppermint taste to contain those other objective facts known as aromatic or sapid quality, and coldness respectively.' We cannot sympathize with Stout's² fear that the view of James involves 'the impossibility not merely of the "analysis of presentation" but of all analysis properly so called,' although we do agree with him that the psychologist's interest is in the psychological and not particularly in the physical object. We cannot agree with Stout, however, against James, (1) because for the former the psychological process must be purely mental, and (2) because he assumes that a perception must be a compound of sensations such as can be analyzed. The issue between a functional and a structural view is definitely brought out here. Stout thinks that because he can remember that oil of peppermint has certain definite qualities of taste and

¹ 'Principles,' I., p. 521 ff.

² 'Analytic Psychology,' 1896, p. 56 ff.

temperature he has analyzed a purely mental thing. Now as a matter of fact the memorial behavior is primarily the implicit functioning of a reaction system developed in direct contact with an object and is therefore most certainly a psychophysiological action. It is precisely because Stout does not see that a reaction system, that is to say the system built up in perceptual contact with objects, can be put into function by a substitution stimulus that he means to perpetuate the mentalistic tradition in psychology. If we assume that what is studied in psychology is the development of the complex reaction patterns and the means whereby they are put into complete or incipient function by various types of stimuli, we need never invoke any mysterious or inscrutable entities.

The literature on space perception clearly demonstrates the hopelessness, from a scientific standpoint, of the mentalistic doctrines. For, the problem of space in mentalistic psychology is the problem of building up or constructing space instead of the observation of the specific means whereby a person performs space reactions and adapts himself to objects variously placed. When space reactions and not geometry is made the subject matter of the psychology of space the problem of the genetic or *a priori* character of space drops out of sight. In the observation and interpretation of space reactions there can be no question of innateness or acquisition of knowledge of space, for a space reaction is not essentially knowledge as we have indicated in our description of the perceptual reaction. There is no doubt, however, that our knowledge of space is derived more or less directly from the space reactions, but this is a problem of logic and not of psychology. The study of the literature on space perception shows us clearly how the psychologists persist in forcing into their science epistemological problems which should have no place therein. Curiously enough the epistemological view gains impetus from an attempt to give psychology a scientific setting as is familiarly illustrated by the influence of Helmholtz's ideas of mathematical space upon the development of the psychology of space perception.

The ascription to current psychologists of a subjectivistic

heritage from Berkeley and Reid may call for some explanation. The statement that we are still working and thinking in the Berkeleyan tradition does not exclude the fact that current introspectionism was established and elaborated by the work of the German physiologists. It is of course a matter of common knowledge that the introspective view was made possible and plausible by the physiological experiment which, dealing with isolated physiological functions, had to assume a correlated mental state to complete the description of the reaction observed. It is thus that the work of the German writers from Herbart through Fechner to Wundt, although designed to place psychology upon a sound scientific basis has in reality, because of its maintenance of the subjectivistic tradition, accomplished the opposite.

The proposed interpretation of the perceptual reactions suggests the extrusion of the separation doctrine from psychology and thus makes toward the removal of what is probably the greatest hindrance to the thorough establishment of psychology as a science. For, as long as psychology deals with conscious or mental states of any sort whatsoever it cannot ever attain to the dignity of a science as Kant long ago asserted. This statement holds whether consciousness is taken as an attribute of the psyche or mind, or of the states of consciousness and unconsciousness which are presumed to be the mind.

In conclusion, we might point out that although the organic conception of psychological phenomena appears to some psychologists as widely accepted,¹ the manifest predominance of the mentalistic and behavioristic views would seem to indicate the contrary. The apparent prevalence of the organic conception may be accounted for on the principle that insofar as a psychologist is to describe some actual psychological fact, the description must in some fashion correspond to the fact, regardless of the private view of the writer. Thus, much of current practice may be organic, but the question remains whether psychology can make much progress toward scientific

¹ Cf. Carr, PSYCHOL. REV., 1917, 24, 182. "The conception is unorthodox only in relation to prevailing definitions of psychology. To my mind it is essentially in harmony with the dominant point of view of the science, and it is not wholly inconsistent with much of current practice."

stability if psychologists do not fully appreciate the character of the materials with which they deal. While it is certainly true that definitions may linger far behind practice, the scientific practice in which this occurs, lacks much in desirable effectiveness. Even if scientists were forced to recognize all the component functions of a reaction, they might still be lacking in a full appreciation of the organic interpretation of such a reaction. That there is little genuine interest in the psychophysiological view among psychologists is evidenced by the general paucity of articles written from that standpoint.¹ Undoubtedly true it is, that the biological influence in psychology has fostered the unitary conception of organisms, but it has not resulted in any complete modification of viewpoint. In fact, the rise of the behavioristic movement urges the belief that there is no general tendency to look upon psychological phenomena as they naturally function but as they are traditionally supposed to operate. A sympathetic acceptance of the objective functional view must result in the description of the complete actual psychophysiological reaction pattern, and the consequent rejection of the exclusively mental or physical interpretation.

¹ Two notable exceptions must be here referred to, namely, Carr, 'The Relation between Emotion and its Expression,' *PSYCHOL. REV.*, 1917, 24, 369, and Peterson, 'The Functioning of Ideas in Social Groups,' *PSYCHOL. REV.*, 1918, 25, 214.

INSTINCT AND PURPOSE

BY EDWARD CHACE TOLMAN

University of California

This paper will be roughly divided into two parts. The first part will present a definition of instinct. The second part will use this definition in a psychological analysis of purpose. The discussion will be throughout from an objective, external standpoint, that is, the interest will be in how purpose works rather than in how it feels.

By way of introduction let us liken the human being to a slot-machine. The pennies will represent the stimuli, *i.e.*, the sights, sounds, printed symbols and the like which we may apply to the machine, and the resulting pieces of candy the words, action, and movements which issue forth. If the penny be a word of praise, the answering candy may be a blush or sparkle of the eye. If the coin we apply be an insult or a blow, the resulting packet will probably contain vituperation. If the penny be the word 'white' spoken suddenly and in no particular connection, the answering phonograph sound will in all probability be the word 'black.' In every case, if we but knew the mechanism well enough, we could predict a particular action as the result of a particular stimulus.

But let us see in what ways this picture of the simple slot-machine is inadequate. We may note that sometimes when a stimulus is presented to the human machine, nothing externally observable issues forth; or, again, that something quite different from a previous response to the very same stimulus comes out. These facts of the uncertainty and changeableness of response in the human machine, though one and the same stimulus be presented, require the assumption of two principles not contained in the simple machine so far described. The first of these principles is that the nature of the response on any given occasion, or whether in fact there is any overt response at all, is dependent upon the general

internal adjustment of the organism at the moment. To make a slot-machine adequate to such a situation we would have to imagine a complex machine capable of various different adjustments such that, when one adjustment was in force, the succeeding pennies produced musical sounds, when another was present, the same pennies introduced into the same slots produced different kinds of candy, and so on for each different adjustment. Finally, we would have to assume in addition that some of these internal adjustments might act like partial locking devices such that, when they were in force, no response at all would be produced from some single penny or for some particular group of pennies.

These internal adjustments would sometimes arise primarily as the result of just preceding external stimuli and sometimes as due almost wholly to automatic changes within the organism itself. If a man refuses food (*i.e.*, if the eating response is locked), it may be because of a preceding stimulus such for example as a slap in his face which has aroused the internal adjustment which we call anger (which locks the eating responses); or it may be because of some automatic physiological condition (*e.g.*, lack of hunger) which, though not positively locking, at least does nothing to unlock the eating responses. If a man responds to one and the same book on one day with tears and on another with laughter, the change in internal adjustment bringing about the change in response may be due either to a specific preceding stimulus or to some mere physiological rhythm.

The second principle which the simple slot-machine lacks and which it should possess, if it is to adequately represent the human organism, concerns the changeableness of response in the human organism which is due to learning. Everywhere we find that, simply as a result of previous experience, the organism exhibits new responses to stimuli. When a child learns to play the piano it acquires a series of finger movements in response to black marks on paper to which, before, it did not react at all. When one learns to read and write, to play tennis, to open and close doors, to lace and unlace shoes; when, in short, one learns any of the million and one things

which one does learn, one is merely attaching responses to stimuli which did not originally call them out.¹

No easy way of representing such alteration in the case of the slot-machines, however, suggests itself. We will, therefore, have to think of the latter as illustrating but single stages in the human organism and imagine a new and improved machine as a result of each acquisition of new traits and habits.

To sum up: the human being is a mechanism which makes responses to external stimuli. The nature of these responses and whether there is any overt response at all, however, is a variable matter. This changeability depends, first, upon the possibility of different internal adjustments (either called out by specific external stimuli or as the result of internal physiological rhythms), and second, upon the changes in the internal structure of the organism due to learning.²

Our task must now be a more specific classification and description of such responses and internal adjustments. Different classification would no doubt be possible, but for our interest, which is concerned primarily with a definition of instinct, the necessary classification is simple. It contains but three groups: (1) independent reflexes, (2) subordinate acts, and (3) determining adjustments.

By an independent reflex we shall mean any response to a stimulus which takes place always in the same manner and relatively independently of what the rest of the organism is doing. The kick of the foot in response to a tap on the knee, winking in response to a movement before the eyes, sneezing in response to tickling the nose, yawning in response to certain internal sensations, are examples. These always occur in much the same way and each is relatively complete in itself and independent of what the rest of the organism may be doing.

Activities on the other hand, such as biting, chewing,

¹ And this holds, be it noted, not only for actual overt responses, but also for the internal adjustments we have just discussed. Thus, for example, the internal adjustments originally appropriate to and only aroused by such things as loud sudden noises and really startling objects may as a result of training get attached to a whole series of secondary associated objects such as the dark, strange faces, etc.

² Also upon changes resulting in the course of natural growth, e.g., the appearance of new sets of instincts as the child matures.

swallowing, which form part of larger wholes—in this example, eating—would be classed in the second group: *i.e.*, termed subordinate acts. The members of this group are almost infinitely numerous. The leg movements of walking, the handlings of curiosity, the cries and shouts and strugglings of anger, the sighing and tears of sorrow, the facial expressions, words and gesticulations of love, would all be examples. In fact all the things we do, not as separate and independent reflexes, but as parts of bigger groups of activity, belong to this second class.

Finally we have as our third group what we called determining adjustments. These are, in fact, to be considered as identical with the internal adjustments just described in our picture of the slot-machine. They determine and set in readiness the subordinate acts. Whether one responds to one and the same stimulus with the subordinate acts of handling and manipulation, those of destruction, or those of rejection, depends upon which particular determining adjustment has first been aroused—whether one of curiosity, one of anger, or one of fear.

It is to be noted that determining adjustments often occur in hierarchies. What may be called the lowest one of the hierarchy is then the immediate determining adjustment for the actual subordinate acts. The next higher one of the hierarchy releases this lowest one. A still higher one releases that, and so on. For example, we may suppose that on a given occasion an individual's leg and foot movements are directly subordinate to what may be called the walking adjustment. This walking adjustment, however, we may assume is subordinate to an anger adjustment. (The man may be on his way to confront a business opponent.) This anger adjustment will then be subordinate to a business adjustment and, finally, this business adjustment itself may be assumed to be subordinate to what may be called the man's general socio-domestic adjustment. In the case of such a hierarchy of adjustments it is obvious that the function of all, save the lowest one in the sequence, consists in a release of a lower determining adjustment rather than in a release of actual subordinate acts.

One further point. In the case of activities such as eating, running, walking, is it legitimate to talk of a determining adjustment as something existing in addition to the individual walking or eating movements themselves? The reason I assume that there is a distinct walking adjustment rather than that the individual walking movements are released directly by the next higher adjustment (for example, the anger of the above illustration) may be indicated first by the case of the child. In the case of a baby, the individual walking movements are obviously very irregular and variable. Yet (when the child is in the 'walking vein') they are all *walking* movements: they all fall within that one general class. Now, wherever these two phenomena occur, of variability within a class of movements and persistence of the class as a whole, my thesis will be that we must assume a specific determining adjustment.

In an adult the situation (in the case of walking) would seem to be somewhat different because of the added influence of habit. With the advent of habit there come fixed and invariable sequences (in the case of walking, fixed and invariable sequences of foot and leg movements). This being the case, the assumption of an immediate walking adjustment to release and maintain walking movements, as such, would not seem so necessary. The total complex of movements is nearly equivalent to a single act and as such would seem a candidate for the *immediate* control of a higher adjustment, such, for example, as the anger of the preceding illustration. It may be noted, however, that in unusual situations such as unevenness or obstacles in the path, this unitary and automatized character of walking may break down, in which case the original walking adjustment would seem again to have to come to the fore to release further walking movements not part of the automatized act.¹

This discussion has brought out three important points

¹ This last point, however, I do not necessarily desire to stress. I would be willing to admit the possibility that with the growth of habits the original determining adjustment upon which these habits are built up recedes and may even entirely disappear (waning of instinct). And, if such is the case, the total habit becomes an alternative act *directly* at the service of higher adjustments.

concerning determining adjustments which it will be well to summarize. (1) The determining adjustment sets in readiness a particular group of subordinate acts. One and the same external or internal stimulus may call out quite different groups of subordinate acts according to the particular determining adjustment which happens at the time to be aroused. (2) Determining adjustments often occur in hierarchies, the higher ones calling out the lower ones and the lowest one of all calling out the actual acts. (3) The essence of the determining adjustment and the reason for it consists in the variability of the subordinate acts. If such variability has disappeared, as is the case where habits have developed, the determining adjustment tends to atrophy and may, perhaps, even disappear altogether.

Let us here stop and assert that determining adjustment as thus characterized is a definition of *instinct*.

It would appear that such a definition tends to differ primarily from most others by virtue of its two-level conception (determining adjustment underneath, subordinate acts on top). Most other definitions seem to reduce in the last analysis to the assumption that an instinct (on the objective side and before learning has affected it) is a definite and stereotyped action (*i.e.*, that it is an inherited reflex pattern).¹

Two authors, however, I have found who suggest views similar to mine. They are Woodworth² and Kempf.³ The former's conception of 'drive and mechanism,' and the latter's 'autonomic and projicient systems,' both suggest a two-level account.⁴ My idea of determining adjustment and subordinate

¹ To take an introspectionist on the one hand and a behaviorist on the other: such a view seems to be that of both McDougall and Watson. See W. McDougall, 'Social Psychology,' p. 29 and following, and J. B. Watson, 'Behavior,' Chs. IV. and VI.

² R. S. Woodworth, 'Dynamic Psychology,' Chap. II.

³ E. J. Kempf, 'The Autonomic Functions and the Personality,' Nervous and Mental Disease Monograph Series, No. 28. See also an article by G. A. de Laguna, PSYCHOL. REV., 1919, 26, especially page 419, for a discussion of emotion significant for the present theory.

⁴ Woodworth might object to his theory being called two-level, since he seems to hold that one and the same apparatus may function either as a drive or mechanism according to circumstance (*i.e.*, that the difference between drive and mechanism is functional rather than structural). But from the point of view of function, if not structure, his is a two-level theory.

act would differ from either of theirs only, first, in leaving speculation as to the actual mechanism of the thing open; and, second, and most importantly, in emphasizing the *variability* among the subordinate acts.

It is this variability which I now particularly wish to emphasize. It will be found especially significant when we turn to the analysis of purpose.

By way of introduction to that analysis, let me now quote two concrete descriptions of animal behavior. First an account of nest building by Prof. Swindle.¹ The bird observed was a male, one of a pair of Brazilian birds, in a large outdoor cage in a zoo.

"Early in April, I noticed that as this bird walked about in its cage, it occasionally bit in the air as if it were grasping an object. At times, however, it bit the bars of its cage, a branch of a tree, and even the naked earth. Sometimes, it sprang and ran rapidly, and it very often flew to a one-and-a-half meter post on the top of which a wide shallow basket was fastened. On April 18, 1915, the following movements were observed: The bird stood at first motionless in the basket, shortly it began biting in the air as if attempting to seize something, and occasionally it seized, lifted, and then dropped certain branches which lay in the basket. It threw a stick out of the basket onto the ground, gazed for a few seconds at the sky, grabbed still another twig which it had previously thrown out of the nest, flew back into the basket with these, beat them quickly here and there without releasing them, let them fall in the basket, bit and arranged them there, and then remained for many minutes by the side of the female which was then also in the basket. Presently the male, half-springing and half-flying, reached the ground, ran quickly to and fro in the cage, gazed for a while at the female as he walked round and round the post, and finally sprang and seized a twig which projected from the basket. This twig was unfortunately so badly tangled with the others of the nest that a great many were drawn out with it. But in spite of the fact that the nest was occasionally mutilated by the builder, a neat nest was eventually constructed."

¹ E. P. Swindle, *Amer. J. of Psychol.*, 1919, 30, 180.

The startling thing about this account is that it indicates that, even in the case of those supposedly perfectly adaptive instinctive activities such as nest-building, careful observation may show a considerable amount, and in this case indeed a positively shocking amount, of variability, the very point we wish to emphasize. If the reader is inclined to doubt the validity or general applicability of this one case, I may quote a word or two more.

The author says, further: "The fact deserves emphasis that birds often work very crudely while building the nest. It is really astonishing how often a bird allows objects of building material to fall, apparently without responding further to them. A bird frequently stands or walks among objects which it could well use in constructing its nest but suddenly runs or flies away without grasping any of them. I have observed the Blue Jay to tear the leaves, branches, and feathers from another bird's nest before it seized an object of the foreign nest and flew to the one which it had started; and it often seemed to arrange the objects on the foreign nest as if it were preparing to deposit its own eggs there, which it did not do."¹

And, again: "Many birds can build their nests at only certain portions of the trees which are adapted to hold the collected objects, and generally, these places are located by the birds only after a number of trials. That this fact is not well known seems to be due to the circumstance that it is very difficult to observe a bird with sufficient scientific accuracy in freedom. It should also be mentioned in this connection that birds occasionally start two or three nests simultaneously and later destroy some of them to obtain the material for a single nest."²

Let us turn, now, to our second case; to wit, Prof. Thorndike's classical experiment of a hungry kitten shut up in a cage with food outside. We quote his words: "When put into the box the cat would show evident signs of discomfort and of an impulse to escape from confinement. It tries to squeeze through any opening; it claws and bites at the bars

¹ Op. cit., p. 178.

² Op. cit., p. 183.

or wire; it thrusts its paws out through any opening and claws at everything loose or shaky; it may claw at things within the box. It does not pay very much attention to the food outside, but seems simply to strive instinctively to escape from confinement. The vigor with which it struggles is extraordinary. For eight or ten minutes it will claw and bite and squeeze incessantly.”¹ It may be added that in the experiment as arranged by Thorndike the kitten usually got out eventually because one of its strugglings quite *accidentally* hit upon a release mechanism arranged to open the door. These mechanisms were always very simple: a hanging loop of wire which required but the slightest clawing, or a wooden latch easily lifted by the nose. It is to be observed that with the opening of the door, a new final act occurred, the cat went out and ate.

I draw attention to the significant feature of both illustrations, the variable or random character of the subordinate acts. In the one case, squeezings, bitings, clawings; and in the other, picking, dropping, carrying. First one act and then another occurs in a perfectly haphazard order. The whole thing seems to be mere chance.

Let us stop, however, and analyze the thing further. Is there any principle underlying the actual order of these, to all outward appearances, purely random acts? It must be supposed that there is. To return to our slot-machine, we must suppose that each one of them is set off by some particular penny, if we could but detect the penny. Now, undoubtedly the pennies are in part internal conditions such as the sensations arising from muscle strain. In addition, however, it is equally certain that they are in part external objects. The stimuli to which the cat’s clawings, biting, etc., are the responses are in part particular features of the cage itself. In so far as they are such features, a definite principle underlying the succession of the responses can be actually observed. The cat, at any given instant, responds to a feature of the cage with which its just previous reaction has brought it in contact. In other words, it carried out a definite train of movements. One

¹ E. L. Thorndike, ‘Animal Intelligence,’ 1911, p. 35.

feature of the cage calls out one response. As a result of the movement made by this response the cat is brought in contact with another feature of the cage. This new feature calls out still another response and so on. If, in between these responses to the successive parts of the cage as such, we imagine a few responses to purely internal conditions, we shall have a fairly exact picture of the cat's total behavior. An identical account could be given of the bird's nest-building activities. Although to all outward intents the acts are purely haphazard and random, still they follow definitely traceable sequences. Finally, at the risk of hammering the point to excess, we may again emphasize that in each case the particular subordinate acts are what they are, rather than other equally possible responses to the same stimuli, by virtue of the particular sensitizing effect of the determining adjustments.

The second feature about the process, to be emphasized, is that the individual random responses continue *until* some one of them presents a new stimulus, the final response to *which*, removes the condition or stimulus which was the original cause of the determining adjustment itself. In the case of the bird, the activity continues until a nest eventually gets built. When this happens we have a new stimulus, the completed nest. And the responses to the completed nest, those of laying and setting, are such as to remove the internal physiological condition which was the original cause of the nest-building adjustment. In the case of the cat, its random acts eventually open the door, whereupon food is presented and the response to food is such as to remove the internal sensation of hunger which was the stimulus to the original food-getting adjustment. In each case the determining adjustment continues, *until* some of its subordinate acts removes the stimulus and with it the adjustment itself.

We have here a fundamental phenomenon. In as much as only one act will remove the adjustment and the adjustment continues *until* that act occurs and in as much as further the adjustment sensitizes and hence, so to speak, supplies the group of acts among which this final successful one appears, it seems to me that we have a situation which may truly be

characterized as one of purpose. A determining adjustment provides the purpose. The subordinate acts (which the adjustment sensitizes) are the means which the organism adopts to fulfill that purpose and the removal of the determining adjustment itself (as a result of one of these subordinate acts) constitutes the fulfillment of that purpose.

If this analysis be accepted, then the goal of this paper, an objective psychological analysis of purpose, is in sight. All that remains to be done is to transfer the account to man. Before attempting this latter, however, let me draw attention to the relation between this definition of purpose, and that of Professor Perry.¹

In Professor Perry's analysis the emphasis is put upon *learning*, upon the fact that with repetition the cat gradually *learns* the successful act. It is in the fact that the successful act is selected (learned) and the other acts rejected, that Professor Perry sees the primary justification for calling the situation teleological. I, on the other hand, believe that even without learning, the situation is teleological. Even though the cat showed absolutely no evidence of learning to get out in a shorter time on succeeding trials, the mere fact that on each single trial it hits about *until* it gets out, seems to me to be sufficient to characterize its activity as purposive. The cat hits about *in order to* get out, *for the sake of* getting out—expressions which Professor Perry himself designates as the 'most unmistakably and unqualifiedly teleological expressions in common use.'

It will be noted that such situations do not imply anything essentially non-mechanical. Given the environment and the total condition of the organism, the complete response (*i.e.*, the particular succession of subordinate acts and the time of the appearance of the final successful one) can all be predicted in a wholly deterministic way. This, however, is no criticism of the definition. When we are talking mechanism we would be very much upset to find something which was not mechanical.²

¹ R. B. Perry, 'Docility and Purpose,' PSYCHOL. REV., 1918, 25, 1-20.

² It should be emphasized that my definition differs from Prof. Perry's principally in not going quite so far. The essential idea for my conception was for the most

To return, now, to our further problem: we wish to show how this mechanism of determining adjustments (or instinct) and subordinate act works in man. One preliminary remark, however, may not be amiss. In the preceding descriptions we spoke as if the random struggles of the cat or the bird always ended in success. As if, that is, when the activity ended, it was always because a response was finally made which removed the initiating stimulus for the determining adjustment. But such an ending, though from the point of view of purpose the successful one, is by no means the only mechanically possible one. Instead of the cat's getting out and eating the food, some other powerful adjustment may intervene and replace the food-getting. Thus it may become frightened by the bruises and bumps that it receives as a result of its struggles so that a *fear* adjustment gradually sets in and replaces the original food-getting one. Hence when the door finally does open, the cat either continues to struggle or runs off and hides instead of eating. In such a case the original food-getting adjustment has not been satisfied but merely replaced by another. A second way in which the original determining adjustment may not be 'satisfied' may be as a result of exhaustion. The cat may become so utterly exhausted that all responses cease to be made. 'It gives up trying.' *Only if some subordinate act takes place which was released by the determining adjustment and which removes the stimulus to that adjustment can the purpose as such be said to be fulfilled.*

Let us now turn to man. In the case of a single purpose I believe that the situation is essentially identical to that represented by the cat struggling to get out of the box or of the bird struggling with sticks and straws. An instinct or determining adjustment is aroused. This facilitates and sensitizes one particular class of subordinate acts. Some one or group of these, if they occur, remove the stimulus to the original instinct and, if they do thus occur, we say, speaking in purposive part drawn from Perry's discussion. It may be noted, however, that determining adjustment and subordinate acts, though analogous to, are not exactly identical with Professor Perry's 'higher propensity' and 'lower propensities.' I believe, indeed, that my two concepts are, for the purposes of behavioristic treatment, more precise and definite than his.

language, that our problem has been solved, that the right means have been chosen.

We may make the issue more concrete by an example. Imagine a man trapped in a burning hotel. He *may* rush madly about in the same blind fashion as does the cat in the cage. If so, his behavior and that of the cat would seem to be entirely identical. It may happen, however, that instead of thus rushing blindly he stops to *think*. If such be the case, he does not attack all the exits of his trap indiscriminately, but only some one which is apparently suggested to him by his 'thoughts.' We have in these thoughts a new principle which does not hold or, if so, to an infinitesimal extent in the case of the cat.

What, now, we may ask, is this thought and when and why does it occur? It will be remembered that in the initial statement of our program we declared that it was an objective, behavioristic account rather than an internal subjective one that we should aim to achieve; that we were interested not in how purposes felt, but in how they worked. Can we, now, shift our point of view and begin to talk about apparently internal subjective things such as thoughts? My answer is that thoughts, or at least the kind of thought with which we are here concerned, can be conceived from an objective point of view as consisting in internal presentations to the organism (on a basis of memory and association) of stimuli not actually present but which would be present, if some hypothesized action were carried out. Such a definition says nothing about the subjective 'immediate-feel' side of thoughts as such. It is concerned with thought simply in so far as the latter has significance in an objective, behavioristic, stimulus and response account. A complete treatment of thought on its subjective (immediate-feel) side and of its epistemological significance we can leave to the combined researches of introspective psychologist and philosopher.¹ The one point we here mean

¹ In what follows I present one sample of the way in which 'thoughts' may, it seems to me, be properly introduced into what claims to be a purely behavioristic (stimulus and response) account. It is my belief that such examples might be indefinitely multiplied and that a whole system, properly to be called behavioristic psychology, might be built up in which thoughts (on their behavioristic side) would still find as much place as do sense-stimuli.

to make is that over and above whatever these functionaries may have to say, a significant behavioristic aspect of thought still remains.

To return to our definition itself. What we mean by thought in this particular case as 'an internal presentation to the organism (on the basis of memory and association) of stimuli not actually present but which would be present, if some hypothesized action were carried out,' can be made clear perhaps, only by a concrete example. We come back to our man in the hotel. Instead of trying all possible parts of his burning trap, we find him stopping to *think* and then on the basis of that thought reacting to certain parts only. What is this stopping to think in behavioristic terms? It consists, I would assert, in what may well be called, not random subordinate acts, but random subordinate *thoughts-of-acts*.

You will remember that the cat reacted to a part of the cage with which the just preceding response had brought him in contact. As a result of each successive response the cat was automatically provided with a stimulus for another response. How now in the case of the man? He sees a door but instead of actually responding, he merely thinks of responding. He hypothesizes a response and on the basis of this hypothesized response he achieves mentally, a new stimulus, *i.e.*, the mental image of what is beyond the door. (This mental image is provided by memory or association. He may actually remember that this door leads to a corridor or merely by association based upon the general position be merely led to imagine that it leads to a corridor.) In either case this idea or mental image of what is beyond acts as a stimulus to a new thought-of-act. He thinks of going down the corridor and this will lead, mentally, to still a new stimulus of what is at the end of the corridor, perhaps stairs or an elevator. These will lead in a flash to a mental image of an open road to the outside. When the image of the latter occurs he will in all probability actually react. If no such vision of an open road beyond stairs or elevator occurs, he will mentally rush back, or perhaps more truly speaking jump back, to his starting point and mentally attack some other feature of his environment.

One point in need of immediate further elucidation emerges. Why is it that the man thinks in the first place? We have already said that sometimes he does not think but merely rushes blindly about as does the cat. Stopping to examine the matter more carefully, it would seem that those times when he does not think, but does thus rush blindly about, are times when he is excessively frightened. Occasions, in short, when the original determining adjustment is especially potent. If, therefore, a particularly potent adjustment produces action, I should suggest that when action does not occur, it is when some inhibiting or checking process which works against or controls the determining adjustment is also acting. Just what, physiologically, this inhibiting or checking process may be, I shall not venture to say, though I shall assume that like all other physiological processes it follows perfectly definite mechanical laws. The significant thing, for us, is simply that it works against the determining adjustment in such a way as to *shunt* the latter's activities, so that instead of producing subordinate acts, it, the determining adjustment, produces merely thoughts-of-acts. For this reason, let us call it the thinking or rationalizing adjustment. We may note in passing several interesting things about this tendency. First it seems to be much stronger in some individuals than in others and secondly, to be very much subject to training and practice. In fact it can sometimes be so over-trained as to result in an almost complete inability to act at all, a condition which is sometimes supposed to be characteristic of the typical college professor.

We may now ask, how is it that this thinking, rationalizing tendency, having once got going, ever ceases, in order to allow action to take place. In answer, we would posit the general principle that action eventually occurs because of what we shall call a prepotent stimulus. A stimulus may be prepotent for either of two reasons: (a) because it is the stimulus to an act to which the original determining is particularly favorable or (b) because it releases some other favorable adjustment. To return to the example of the man in the hotel. The first case would be represented when as a result of his trains of thoughts-

of-acts he arrives at the mental image of open road beyond stairs or elevator. Such a sight of the outside, if present in perception, would be the *one* stimulus to which the man would have been *most* sensitive. If the door in the cat's cage had been left open, the response of going out would have been *first* to occur. It would have taken precedence over all other responses such as those of squeezing, clawing, biting. So, here, the thought of the open road beyond stairs or elevator is the stimulus to which the given determining adjustment makes the man most susceptible, so susceptible in fact that the impulse is enough to break down the inhibiting effect of the thinking propensity and action results.

Turn, now, to the second way in which the stimulus may be prepotent: the case in which it is prepotent because it releases a second adjustment favorable to the given action in addition to the original adjustment. Suppose that as a result of social intercourse our man had acquired a general maxim to the effect that stairs and elevators become perfect smokestacks and that much the best thing to do in case of fire is to run to the window and call for help. Simply on the basis of his original determining adjustment alone the thought of the window would tend to call out the subordinate act of going and calling. If, now, in addition such an act is supported by what we may call a general 'social-subservience' adjustment, a tendency to do those acts recommended by society, this act becomes doubly ready to go off, so much so that it does actually occur.

To sum up: thought ceases and action supervenes whenever thought arrives at the image of a prepotent stimulus. And a stimulus is prepotent either (*a*) because it tends to call out a subordinate act which is especially favored by the original determining adjustment or (*b*) because it tends to call out in addition to the original determining adjustment some other adjustment which is also favorable to the act.

This is all there is to a case of single purpose.¹ An original determining adjustment provides the purpose. Subordinate

¹ The problem of what happens in the case of a conflict of purposes is more complex, but the general principles of explanation would be the same.

acts are either actually called out or merely thought of. Eventually one occurs which removes the stimulus to the determining adjustment and the purpose is satisfied. Or, if no such subordinate act occurs, it remains unsatisfied until, perhaps, mere exhaustion causes the determining adjustment to disappear.

In conclusion, we may briefly enumerate the more important points we have advanced and which we most wish to emphasize: (1) a two-level (*i.e.*, determining adjustment—subordinate act) theory of instinct; (2) Purpose as interaction of determining adjustment and subordinate acts; (3) images of memory and imagination (thoughts) as properly included in a behavioristic non-introspective account; (4) the satisfaction of purpose as consisting in the removal of the stimulus to the determining adjustment as a result of one of the subordinate acts which the determining adjustment itself releases.

BRAIN MECHANISMS AND MENTAL IMAGES

BY S. BENT RUSSELL

St. Louis, Mo.

When you think of an absent friend you may seem for an instant to see his face, *i.e.*, you have a mental image of his face. This is commonly said to be due to memory. But what then is memory? There may be readers of this article who have considered memory only from the subjective point of view. Let us for the moment now consider memory apart from the matter of images and consider it from the objective point of view. It can be shown that memory is accounted for by the operation of nerve processes. There are pathways along nerve fibers for nervous impulses. Some of these are known as association pathways. There is good reason to believe that changes of resistance at the points of junction between nerve fibers known as synapses, determine the course of nervous impulses along one path or another. The frequency and recency of previous impulses determines the synaptic resistance. Hence the nerve paths are developed by individual experience and thus memory is evolved.

The dual common path theory furnishes an explanation of associative memory. The common path is open to impulses coming from two tributary or private paths. An impulse from one lowers the synaptic resistance for an impulse from the other. We need not go further into this theory in this discussion. Let us take it as an explanation of associative memory for the purposes of this demonstration.

Before you can have a memory image of an object you must at one time be conscious of the object itself. Let us consider briefly how perception can be explained in terms of nerve processes. A man is never conscious of an object unless there be communication from the object to his brain. We may say further that there must also be a molecular change at some brain center or centers that bears a correspondence to the

object. In other words, the object causes a nerve impulse from a sense organ to a brain center and the impulse causes a response (molecular) at the brain center. To mention a special case, when a point on the retina is stimulated by a ray of light from some object, there is an impulse sent by way of a certain nerve fiber to a certain nerve center in the cerebral cortex, where it provokes a molecular response that corresponds to the retinal stimulation. We see that each visible point of the object has a line of communication by way of the retina and a particular nerve fiber to a brain center. All the points together produce a pattern molecular response in the brain. This joint response simulates the object in view.

Let us for convenience use the term 'mimetic response' to express the molecular response that simulates the object as represented at a sense organ.¹

To put it another way, there is a registering mechanism in the brain center that transforms the afferent impulse into light equivalent, heat equivalent or other sensation equivalent as the case may be. That is, it in effect reverses the transformation that occurred in the sense organ. When a ray of red light for example falls on the retina, there is a change in the brain center the same as if a red light had penetrated it. Let us term this hypothesis 'the mimetic theory of perception.'

This explanation of perception is not complete unless we make allowance for the effect of association mechanisms. You will see this if you think of a trained musician listening to a well-known melody on one hand, and a man without any musical training listening to the same melody for the first time on the other hand. The brain correspondence will be far greater in the former case. Every individual has to be trained to see and hear things as they are. Brain correspondence increases with knowledge, *i.e.*, with the development of associa-

¹ The writer has presented an explanation of mechanisms of associative memory and of their functions in intelligent and purposive behavior and in consciousness in the following articles in the PSYCHOLOGICAL REVIEW. 'The Effect of High Resistance in Common Nerve Paths,' 1916, 23, 231-236. 'Compound Substitution in Behavior,' 1917, 24, 62-73. 'Advance Adaptation in Behavior,' 1917, 24, 413-425. 'Communication, Correspondence and Consciousness,' 1918, 25, 341-358.

tion mechanisms. In other words, a man's habits determine the definiteness of his perception.¹

We must also make allowance for the effect of language and other forms of expression upon perception. Naming and numbering are great helps in perception. In learning to describe his environment, a man develops association nerve paths that serve to increase his brain correspondence with the world he lives in.

Keeping these matters in mind, we can say we have in the mimetic theory, a satisfactory explanation of consciousness as it reflects a man's present environment. The purpose of this discussion is to bring out an explanation of the memory image in terms of nerve processes. Before attacking the problem, let us note the difficulties we have to meet. It is not so hard to conceive how a ray of red light can cause a disturbance in a brain center that is characteristic of redness as it is to conceive of a nerve impulse aroused in the ear by the sound of the word red, for example, producing a disturbance in a brain center that is so characteristic of redness that the subject will for an instant see a red color in his mind. That is, he is conscious of red when there is in reality no red to be seen. There is, you will allow, an apparent paradox. Why should an impulse coming from the ear, arouse an image of light? We can think of a ray of red light penetrating a brain center and causing a characteristic molecular disturbance like a light ray acting on a photographic plate. We can go another step and think of a ray of red light stimulating a sensory nerve ending and so causing a nerve impulse which goes to the brain center and by aid of a special mechanism reproduces there the disturbance at the sensory ending caused by the red ray and characteristic of redness. But why should some other kind of stimulus produce a molecular disturbance that has a quality belonging to red?

In other words, if we seek explanations in terms of nerve processes, the one for consciousness of the past is far more difficult than that for consciousness of the present.

On account of the obvious resemblance, the memory image

¹ W. B. Pillsbury, 'The Essentials of Psychology,' 1911, p. 157.

is often considered as composed of sensations that are centrally aroused instead of coming from the effect of the environment acting directly as in perception. In these terms we would note that an explanation of a centrally aroused sensation by nerve processes is by no means as simple as in the case of a true sensation. If the reader can see the point of difficulty it will help him grasp the demonstration given herein.

As the next step let us take for illustration the case of a young man of normal mind sitting in a boat and drifting down a river. As he drifts along he observes different objects along the bank and of course is conscious of each in turn. Let us say it is the second time he has made this voyage. He will have from time to time mental images of objects that have passed out of view and sometimes he will have an image of an object ahead of him that will soon come into view. Suppose at one time he passes a gravel bar on which he sees a flock of white cranes. Later on he passes another gravel bar and has a memory image of the white cranes. At one time he passes under a railroad bridge and is startled by the roar of a train. Later on he passes another bridge and has a memory image of the roar. Let us see if we can find an explanation of these memory images in terms of nervous mechanisms.

In a book published some years ago, Professor Kirkpatrick describes images as the result of the functioning of brain centers that are made active in perception by impulses coming from sensory centers, while in imaging they are made active by impulses coming from some other direction.¹ The theory that will now be advanced does not conflict with Dr. Kirkpatrick's view.

Returning to our illustration, when the man observes an object in the first instance, there is, as we have already stated, a molecular change in the cerebral cortex that simulates the object and which we term the mimetic response. That is not the whole story, however, as there is another process too. In the case of vision for example, the mimetic response only lasts while the retina is stimulated by the object or for a moment more. There is a second process that is a recording

¹ E. A. Kirkpatrick, 'Genetic Psychology,' 1909.

process. Let us call this record making process the 'tuning process.' It is a specific molecular change that is more permanent than the mimetic response. There is one tuning process for light, one for sound, one for heat, etc. After the tuning process has occurred in a certain center, any nerve impulse that reaches the center will cause a molecular disturbance that simulates the original stimulus disturbance in the sense organ. In this way we have correspondence of a brain center with a past environment. This simulating process in the nerve center is, we will say, a conditioned molecular response. Let us term it the 'sounder response.'

In our illustration when the man is conscious of his present environment, there is a series or procession of impulses through certain brain centers. In other words the mimetic response is a series of molecular changes in the brain centers that bears a correspondence to the environment. The tuning process is also a series of molecular changes that bears a correspondence to the environment. At the same time it leaves an impression on the molecular structure that also bears a correspondence to the environment. We may liken the mimetic response to a gust of wind passing over a sheet of water and causing a ripple that is soon gone and we may liken the tuning process to a gust of wind passing over a smooth sand bed and leaving the familiar ripple marks that remain for a time.

The sounder response is conditioned by the tuning process. It is a series of molecular changes that bears a correspondence to the environment that caused the tuning process. There must of course be a specific sounder response that corresponds to light and another that corresponds to heat and another for sound and another for taste, etc. When a man has a memory image of a noise he heard a minute ago, there is in one of his brain centers a sounder response that is provoked by a nerve impulse coming, we will say from some association nerve path. The effect is the same as if there were communication from the noise-making object to the brain center that took a minute to reach the brain center. It is something like the thunder peal that reaches the ear some seconds after the lightning stroke that made it.

In the same way when a man has a memory image of an object that has recently passed out of view, there is in one of his brain centers a sounder response that is provoked by an impulse from some association nerve path. The effect is the same as if the object were still in communication with his brain. In his mind's eye he sees perhaps a red triangle although there is no red triangle now present to stimulate his organs of vision.

Let us now consider the tuning process again. A harp string can be tuned by turning the peg that holds it and thus changing the tension. With a given string a certain tension will produce a certain note, say C. Now a certain tension means a certain relation of the molecules to each other. The tuning operation produces a certain molecular arrangement that corresponds to the note C. As long as this molecular arrangement is preserved the string when struck will give the sound of C. The note C is of course a vibration at a certain rate and thus we see the molecules are so arranged by the tuning operation as to give when struck, a certain response. We may use the harp string as an illustration of a brain center. We may suppose that a nerve mechanism exists by which a certain brain center can be brought into a certain molecular arrangement so that thereafter any nerve impulse will produce a particular response or movement.

The tuning process is, we have stated, a change in the molecular structure. We may compare it to the alteration in litmus paper that is changed in color from red to blue when it is wet with an alkaline liquid. We note that after the change the paper gives off blue rays when exposed to light. We may also compare the tuning process to the case of paper that is tinted with some color that is not fast. If a ray of sunlight falls on it, a faded spot remains that will be seen whenever there is any light on the paper and so is a sort of memory image of the sunlight ray. Hence we may think of a bright object in view of a man as causing a little faded spot in his brain that is brought out by any passing nerve impulse that comes later on.

Let us remember that the man is never conscious of the mimetic response or the sounder response. He is conscious

of the object itself that furnished the stimulus, whether it be in the present or past environment. In the case of an image, the effect on consciousness is the same in kind as if the object were still in communication with the brain center.

It may make these explanations more clear to you if they are illustrated by a diagram or table like the one below. Let the features of the object seen in the first instance be represented by the letters A, B, C, D, E, and the impression on the retina be represented by the letters A₁, B₁, C₁, D₁, E₁, and the mimetic response by A₂, B₂, C₂, etc., and the tuning process by A₃, B₃, C₃, etc., and the sounder response by A₄, B₄, C₄, etc. The table follows:

Object	A	B	C	D	E	Object
Retinal image	A ₁	B ₁	C ₁	D ₁	E ₁	Perception
Mimetic response	A ₂	B ₂	C ₂	D ₂	E ₂	
Tuning process	A ₃	B ₃	C ₃	D ₃	E ₃	
Sounder response	A ₄	B ₄	C ₄	D ₄	E ₄	Mental image

Let us now go back to our case of the man drifting down the river. We will take the experience of the bridges. There is a certain center in the man's brain that is reached by a certain nerve path coming from the ear. It is also reached by a certain association path that has one connection with the ear and one with the eye. When the man sees the first bridge, there is an impulse from the eye via the association path and when he hears the roar of the train there is an impulse from the ear via the association path and one via the other path from the ear. The sound impulses cause a tuning process in the brain center. Later on the man observes the second bridge and there is an impulse from the eye that follows the association path more easily as it is now more open because the two impulses in succession, caused by the experience at the first bridge, have made it so. When the impulse reaches the brain center, there is a conditioned molecular response and the man has a sound image of the train roar at the first bridge. Please note that the response simulates a sound although the provoking impulse originates in the eye. This is the apparent paradox that we remarked in the beginning.

You may comprehend the case better when you see it presented in a diagram as in Fig. 1. The circle *V* represents the visual organ, the circle *A*, the auditory organ and the circle *R*, the brain center. At the sight of the first bridge an impulse travels from the eye at *V* by the dotted line path *C* to the center at *R*. The roar of the train sends a second impulse from the ear at *A* by the common path *C* to *R*, and a third impulse by the dotted line path *B* to *R*. The last two impulses provoke a tuning process in *R*. After the first and second impulses have passed over path *C* it is more open to later impulses. The sight of the second bridge later on sends an impulse from the eye at *V* by the path *C* as shown by a heavy line, to the brain center *R*. There is now a sounder response at *R* that simulates the roar of the train at the first bridge. A path line on the diagram of course represents a plural number of nerve fibers.

On consideration you will find that the explanation just given for a particular case will answer for all memory images. There are many cases of course, where a large number of association nerve paths are required to produce a definite memory image. The larger the number, the higher will be the degree of correspondence with the environment at the time of observation.

The association nerve paths must be developed by individual experience. A baby cannot have mental images like an older person. A baby must learn to talk before he can hear words in his mind. He must learn to sing before he can hear a song in his mind. He can only coördinate impressions that have become familiar. He learns to form images step by step. He must learn to walk before he can image distance relations and space relations. We have previously observed that perception is determined by a man's habits to an important extent and the same thing is true of mental images. The study of language and expression, also, must have an important effect in developing the mechanisms for making mental images.

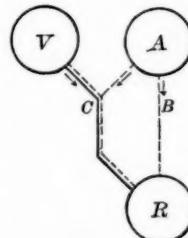


FIG. 1.

A man who has learned how to write a good description of a landscape has no doubt increased the definiteness of his mental images. You are perhaps able to look at a new model of an aeroplane and memorize it so as to have a good memory image of it a week afterwards and have never remarked that your ability to do this is the result of long and repeated practice on similar objects. On consideration you will see that these statements fit in with our theory that the image is due to a conditioned molecular response that simulates a past environment at one time in communication with the brain centers responding.

We find then that a typical memory image accompanies a compound sounder response and is due to the operation of tuning process mechanisms and association mechanisms, the latter serving to coördinate the former.

We have found an explanation of how the brain can simulate a past environment. Let us pass on to the case where the image corresponds with a coming environment. Let us return to our illustration of the man on the river. Suppose he sees in the distance ahead of him a column of smoke and then has a mental image of a landing pier at a village around the next bend. At first thought this appears to be an image of a future environment but on second thought we find that the man's mental image is the result of his previous voyage over the same route. The same rule will apply to all cases where the image appears to anticipate the object. The mental picture of things to come is made up of elements derived from past experience.¹ A man can imagine an aggregate that he has never seen but it will be made up of familiar units. The power of combining mental images is acquired by degrees. It must be largely due to social environment and to language associations. What one man has observed another man can image by the medium of language. The younger are taught analysis and synthesis by their elders.

It is evident then that an image of a coming environment is due to the same nerve mechanisms that serve for the image of a past environment. All mental images are really memory images in kind.

¹ Pillsbury, *op. cit.*, p. 131.

In considering these brain processes, one should keep it in mind that the power to form an image diminishes with time. You perhaps have a clear mental image of a particularly fine cigar that was given you yesterday, but had it been a week ago you probably would have no image to speak of. The longer the time, the less is the conductivity of the association nerve paths and sooner or later the mechanisms will fail to coördinate so as to simulate the past environment.

The kinæsthetic impulses from actual and incipient muscular movements have much to do with provoking sounder responses. Acting, talking and thinking are all linked together by association mechanisms. Behavior habits and language habits serve to prevent the untimely occurrence of sounder responses as a rule. It is not always true, however, as a man can sometimes be reading aloud and at the same time, have mental images having no connection with the words which he is subconsciously repeating.

When a man is awake but resting quietly in an unchanging environment, he is usually unconscious of his environment or, as we say, he is lost in thought. From our point of view there are no mimetic responses in his brain centers and his nerve-muscle system is occupied with a series of incipient muscular movements accompanied frequently by a series of sounder responses in the brain centers. There is a constant flow back and forth of efferent and afferent (kinæsthetic) impulses which penetrate one cortical center after another. Those centers that have been tuned by past experience give a characteristic conditioned molecular response. It is thus that mental images transpire more commonly. The man may be thinking of future events but it is always in terms of what he has seen and heard before.

Having reached these conclusions regarding the mental operations of a man, it will not be amiss to consider briefly the mental processes of animals lower than man. Do monkeys, dogs and other intelligent animals have mental images? We know that the nervous system in these animals is much the same as in man and in behavior also there is much resemblance. The brute learns by experience as does the man. In man we

find great superiority in expression as he has an articulate language which the brute has not. There is, however, communication with the brutes. The baying of a beagle on the trail of a rabbit, no doubt has in its changes more meaning to the other beagles than even to the experienced hunter. The available evidence indicates that the nervous mechanisms in the animal are of the same kind as those in man. Therefore it is probable that a squirrel has a mental image of a nut that he has hidden away for future use, the same as a man would have, and that a fox has a mental image of the bone that he buried and will one day dig up. A bird probably has a mental image of her nest that she built herself with the aid of her mate just as a man has of a hut he has constructed. In the man's brain the association mechanisms are far more complex. The number of association nerve paths is much greater.

In conclusion let us say that a mental image can only occur when there is a coördinated molecular response in a brain center that is conditioned by a former environment. The response is conditioned by means of registering mechanisms in the center and of association mechanisms. The response is the same in kind as if the environment in question were still acting upon the sense organs and so upon the center. The man is not conscious of an image as such but of the environment as it was. He sees it around the corner, one might say. Usually, of course, the response is very much fainter than in the case of direct stimulus from the sense organ in perception.

The registering mechanism at the brain center when in communication with the environment, acts by retransforming the nervous impulses into specific molecular changes that simulate the environmental action upon the sense organ. The result is a permanent set of the molecules that is a factor in subsequent responses to excitation by any nervous impulses that reach the center. The responses in the registering centers are further conditioned and also coördinated by mechanisms of association. These mechanisms function in the same way as they do in the case of conditioned reflexes which cause muscular movements. The same sort of association mechanisms govern the responses in the registering centers as govern the responses in the muscles and other effectors.

The knowledge that a highly intelligent man has of the world about him is due to the brain mechanisms that have gradually become organized and developed from his birth up. This applies also, of course, to a man's knowledge of himself.

Finally we cannot escape the conclusion that in a man's consciousness of past and future, brain mechanisms are an essential factor. Without brain mechanisms a man would have no more mental power and no more consciousness than an apple tree.